PB85-228062

Full-Scale Field Evaluation of Waste Disposal from Coal-Fired Electric Generating Plants
Volume 2. Sections 6 through 9

Little (Arthur D.), Inc., Cambridge, MA

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Jun 85

U.S. Department of Commerce
National Technical Information Service
NTIS

EPA-600/7-85-028b
June 1985

PB85-228062

FULL-SCALE FIELD EVALUATION OF WASTE DISPOSAL FROM COAL-FIRED ELECTRIC GENERATING PLANTS:

Volume II. Sections 6 through 9

by

Chakra J. Santhanam, Armand A. Balasco,
Itamar Bodek, and Charles B. Cooper

Arthur D. Little, Inc.
20 Acorn Park
Cambridge, MA 02140

EPA Contract: 68-02-3167

John T. Humphrey
Haley and Aldrich, Inc.
238 Main Street
Cambridge, MA 02142

Barry Thacker
Geologic Associates, Inc.
10628 Dutchtown Road
Knoxville, TN 37922

EPA Project Officer: Julian W. Jones
Air and Energy Engineering Research Laboratory
Office of Environmental Engineering and Technology
Research Triangle Park, NC 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-600/7-85-028b

2.

3. RECIPIENT'S ACCESSION NO.
PB85 228062 /AS

4. TITLE AND SUBTITLE
Full-scale Field Evaluation of Waste Disposal from Coal-fired Electric Generating Plants: Volume II. Sections 6 Through 9

5. REPORT DATE
June 1985

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S) C. Santhanam, A. Balasco, I. Bodek, and C. Cooper; J. Humphrey*; and B. Thacker**

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Arthur D. Little, Inc.
20 Acorn Park
Cambridge, Massachusetts 02140

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
68-02-3167

12. SPONSORING AGENCY NAME AND ADDRESS
EPA, Office of Research and Development
Air and Energy Engineering Research Laboratory
Research Triangle Park, NC 27711

13. TYPE OF REPORT AND PERIOD COVERED
Final; 10/79 - 10/84

14. SPONSORING AGENCY CODE
EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is Julian W. Jones, Mail Drop 61, 919/541-2489. (*)Haley and Aldrich, Inc., Cambridge, MA 02142. (**)Geologic Associates, Inc., Knoxville, TN 37922. Volume I is Sections 1 through 5.

16. ABSTRACT The six-volume report summarizes results of a 3-year study of current coal ash and flue gas desulfurization (FGD) waste disposal practices at coal-fired electric generating plants. The study involved characterization of wastes, environmental data gathering, evaluation of environmental effects, and engineering/cost evaluations of disposal practices at six sites around the country. Study results provide technical background data and information for EPA, state and local permitting officials, and the utility industry for implementing environmentally sound disposal practices. Study data suggest that no environmental effects have occurred at any of the six sites; i.e., data from wells downgradient of the disposal sites indicate that waste leachate has resulted in concentrations of chemicals less than the EPA primary drinking water standards. A generic environmental evaluation--based on a matrix of four waste types, three disposal methods, and five environmental settings--shows that, on balance, technology exists for environmentally sound disposal of coal ash and FGD wastes for ponding, interim ponding/landfilling, and landfilling. For some combinations of waste types, disposal methods, and environmental settings, mitigation methods must be taken to avoid adverse environmental effects. Costs of waste disposal operations are highly system and site specific.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Ashes	Pollution Control	13B	21B
Waste Disposal	Flue Gases	Stationary Sources		
Wastes	Desulfurization		14G	07A, 07D
Coal	Cost Engineering		21D	14A
Combustion				
Electric Power Plants			10B	

18. DISTRIBUTION STATEMENT
Release to Public

19. SECURITY CLASS *(This Report)*
Unclassified

20. SECURITY CLASS *(This page)*
Unclassified

21. NO. OF PAGES
253

22. PRICE

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

This report summarizes results of a 3-year study of current coal ash and flue gas desulfurization (FGD) waste disposal practices at coal-fired electric generating plants. The study was conducted by Arthur D. Little, Inc., under EPA contract 68-02-3167, and involved characterizing wastes, gathering environmental data, assessing environmental effects, and evaluating the engineering/costs of disposal practices at six selected sites in various locations around the country. Results of the study are providing technical background data and information to EPA, State and local permitting officials, and the utility industry for implementing environmentally sound disposal practices.

Data from the study suggest that no major environmental effects have occurred at any of the six sites. For example, data from wells downgradient of the disposal sites indicate that the contribution of waste leachate to the groundwater has generally resulted in concentrations of chemicals less than the primary drinking water standards established by EPA. Although occasional exceedances of the standards were observed, these were not necessarily attributable to coal ash and FGD waste. A generic environmental evaluation based on a matrix of four waste types, three disposal methods, and five environmental settings (based on climate and hydrogeology) shows that technology exists for environmentally sound disposal of coal ash and FGD wastes for ponding, interim ponding/landfilling, and landfilling. For some combinations of waste types, disposal methods, and environmental settings, measures must be taken to avoid adverse environmental effects. However, site-specific application of good engineering design and practices can mitigate most potentially adverse effects of coal ash and FGD waste disposal. Costs of waste disposal operations are highly system- and site-specific.

APPENDIX A

SITE SELECTION REPORT

FULL-SCALE FIELD EVALUATION OF WASTE DISPOSAL FROM COAL-FIRED ELECTRIC GENERATING PLANTS

By

Chakra J. Santhanam
Armand A. Balasco
Charles B. Cooper
David E. Kleinschmidt
and
John T. Humphrey (Haley & Aldrich, Inc.)

Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts 02140

EPA Contract 68-02-3167

EPA Project Officer: Julian W. Jones
Industrial Environmental Research Laboratory*
Office of Environmental Engineering and Technology
Research Triangle Park, North Carolina 27711

Prepared For

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

(*) Now, the Air and Energy Engineering Research Laboratory

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to a number of individuals and organizations for their help, comments, and input to the principal investigators. In particular, grateful appreciation is expressed to:

Alabama Electric Cooperation - John Howard

American Electric Power Service Corp. - Ron Morrison

American Public Power Association - William Becker

Carolina Power & Light - E.A. Morgan

Central Illinois Light - Larry Haynes

Commonwealth Edison - Thomas Hemminger, Eldred H. Dusold

Conversion Systems Inc. - H. Mullen, Ronald J. Backsai

Duke Power Company - Dave Anderson, Joseph Harwood, and Arnold Gnilka

Duquesne Light - Steve Pernak, John Rocco

Edison Electric Institute - Christopher F. Hughes, Corey Trench, and Brian Farrell

Electric Power Research Institute - Dean Golden, John Maultbesch Ishwar Murarka

Environmental Protection Agency Office of Solid Waste - John M. Heffelfinger and Penelope Hanson

Environmental Protection Agency Office of Environmental Engineering and Technology - Kurt Jakobson

Environmental Protection Agency Robert S. Kerr Environmental Research Laboratory - Jack Keeley

Environmental Protection Agency Environmental Monitoring & Support Laboratory - Eugene P. Meier

ACKNOWLEDGEMENTS
(Continued)

Environmental Protection Agency
MERL-CINN - Norbert B. Schomaker,
Don Sanning, and
Robert Landreth

Gulf Power - George Layman, Ray Harry

Indiana Kentucky Electric - Fred. L. Stokes and Ed Schwarm

Los Angeles Department of Light & Power - Ed Gladbach and
John Schumann

Northern States Power Company - Robert Clough

Pacific Power & Light - Roy Hamilton

Pennsylvania Electric Co. - James. L. Sreco

Public Service of Colorado - Robert L. Pearson

Southern Company Services, Inc. - Randall E. Rush and Lamar Larrimore

Tennessee Valley Authority - Hollis P. Flora, Dotson Luton, and
Sal Magliente

Texas Utilities - John H. Carlson and Richard L. White

Union Electric Company - Jerry Bindle

U.S. Department of Energy - Val Weaver

Upper Peninsula Generating Co. - Robert R. Raisanen

Wisconsin Power & Light - W. Engler

TOP

CONVERSION FACTORS

English/American Units	Metric Equivalent
Length:	
1 inch	2.540 centimeters
1 foot	0.3048 meters
1 fathom	1.829 meters
1 mile (statute)	1.609 kilometers
1 mile (nautical)	1.852 kilometers
Area:	
1 square foot	0.0929 square meters
1 acre	4,047 square meters
Volume:	
1 cubic foot	28.316 liters
1 cubic yard	0.7641 cubic meters
1 gallon	3.785 liters
1 barrel (42 gals)	0.1589 cu. meters
Weight/Mass:	
1 pound	0.4536 kilograms
1 ton (short)	0.9072 metric tons
Pressure:	
1 atmosphere (normal)	101,325 pascal
1 pound per square inch	0.07031 kilograms per sq. centimeter
1 pound per square inch	6894 pascal
Concentration:	
1 part per million (weight)	1 milligram per liter
Speed:	
1 knot	1.853 kilometers per hour
Energy/Power:	
1 British Thermal Unit	1,054.8 joules
1 megawatt	3.600×10^9 joules per hour
1 kilowatt hour	3.60×10^6 joules
Temperature:	
1 degree Fahrenheit	5/9 degree Centigrade

10 Lines to End of Typing Area

AD-054 1279 300M

GLOSSARY

Cementitious: A chemically precipitated binding of particles resulting in the formation of a solid mass.

Fixation: The process of putting into a stable or unalterable form.

Impoundment: Reservoir, pond, or area used to retain, confine, or accumulate a fluid material.

Leachate: Soluble constituents removed from a substance by the action of a percolating liquid.

Leaching Agent: A liquid used to percolate through a substance that results in the leaching of soluble constituents.

Pozzolan: A siliceous or aluminosiliceous material that in itself possess little or no cementitious value but that in finely divided form and in the presence of moisture will react with alkali or alkaline earth hydroxide to form compounds possessing cementitious properties.

Pozzolanic Reaction: A reaction producing a pozzolanic product.

Stabilization: Making stable by physical or chemical treatment.

ABBREVIATIONS

Btu	British thermal unit
cm	centimeter
cm/sec	centimeter per second
°C	degrees Centigrade
°F	degrees Fahrenheit
ESP	electrostatic precipitator
FGC	flue gas cleaning
FGD	flue gas desulfurization
ft	feet
ft/sec	feet per second
g	gram
gal	gallon
gpm	gallons per minute
hp	horsepower
hr	hour
in.	inch
j	joule
j/s	joule per second
k	thousand
kg	kilogram
km	kilometer
kW	kilowatt
kWh	kilowatthour
l	liter
lb	pound
M	million
m^2	square meter
m^3	cubic meter
Mw	megawatt
ppm	parts per million
psi	pounds per square inch
sec	second
TDS	total dissolved solids

Note: For conversion units, see page A-iv.

TABLE OF CONTENTS

Page(A-)

Acknowledgements ii
Conversion Factors iv
Glossary v
Abbreviations vi
Participants in the Study xix
List of Figures xi

List of Tables xiii

EXECUTIVE SUMMARY S-1

1.0 INTRODUCTION 1

2.0 METHODOLOGY AND APPROACH 3

- 2.1 AVAILABLE DATA BASE 3
- 2.2 OVERALL APPROACH 5
  - 2.2.1 Priorities for Site Selection Considerations 5
  - 2.2.2 Approach 7
    - 2.2.2.1 Basis 7
    - 2.2.2.2 Candidate and Back-Up Site Selection 8
    - 2.2.2.3 Final Site Selection 10
- 2.3 REGIONAL DIVISION OF THE UNITED STATES 11
- 2.4 FGC WASTES & DISPOSAL OPERATIONS 14
  - 2.4.1 FGC Waste Types 14
    - 2.4.1.1 Coal Ash 14
    - 2.4.1.2 FGD Sludges 14
  - 2.4.2 Disposal Methods 17
  - 2.4.3 Trends in FGC Waste Generation and Disposal 20
- 2.5 NUMBER OF CANDIDATE SITES 28
  - 2.5.1 Basis for Candidate Sites 28
  - 2.5.2 Targeted Number of Candidate Sites 30
- 2.6 ASSESSMENT OF DISPOSAL OPERATIONS 36
  - 2.6.1 Elimination Criteria 37
  - 2.6.2 Rating Criteria 37

Page (A-)

2.6.2.1 Waste Variability 37
2.6.2.2 Disposal Practices 39
2.6.2.3 FGD System 39
2.6.2.4 Mitigative Engineering Practices 39

2.7 HYDROGEOLOGIC CONSIDERATIONS 41

2.8 OTHER SITE SELECTION FACTORS 47

2.8.1 Regional/Generic Factors 49
2.8.2 Site-Specific Factors 53

2.9 UTILITY COOPERATION 59

3.0 CANDIDATE SITES 60

3.1 REGION A1: GULF COASTAL PLAIN REGION 61

3.1.1 Background 61
3.1.2 Assessment of Disposal Operations 64

3.1.2.1 Categorization of Disposal Operations 64
3.1.2.2 Assessment of Disposal Operations 66
3.1.2.3 Comments on Handling and Transportation of FGC Waste 66

3.1.3 Geotechnical and Hydrogeologic Considerations 68
3.1.4 Other Site Selection Considerations 68

3.1.4.1 Discussion 68
3.1.4.2 Ratings 68

3.1.5 Candidate and Back-Up Sites 68

3.2 REGION A2: PIEDMONT AND COASTAL PLAIN REGION 76

3.2.1 Background 76
3.2.2 Assessment of Disposal Operations 78

3.2.2.1 Categorization of Disposal Operations 78
3.2.2.2 Assessment of Disposal Operations 80
3.2.2.3 Comments on Handling and Transportation of FGC Wastes 80

3.2.3 Geotechnical and Hydrogeologic Considerations 80
3.2.4 Other Site Selection Considerations 86

3.2.4.1 Discussion 86
3.2.4.2 Ratings 86

3.2.5 Candidate and Back-Up Sites 86

Page (A-)

3.3 REGION B: APPALACHIAN REGION 91

3.3.1 Background 91
3.3.2 Assessment of Disposal Operations 92

3.3.2.1 Categorization of Disposal Operations 92
3.3.2.2 Assessment of Disposal Operations 98

3.3.3 Geotechnical and Hydrogeologic Considerations 98
3.3.4 Other Site Selection Considerations 98
3.3.5 Candidate and Back-Up Sites 119

3.4 REGION C: NEW ENGLAND REGION 122

3.4.1 Background 122
3.4.2 Assessment of Disposal Operations 123

3.4.2.1 Categorization of Disposal Operations 123
3.4.2.2 Assessment of Disposal Operation 126
3.4.2.3 Comments on Handling and Transportation of FGC Wastes 126

3.4.3 Geotechnical and Hydrogeologic Considerations 126
3.4.4 Other Site Selection Considerations 126
3.4.5 Candidate and Back-Up Sites 126

3.5 REGION D: INTERIOR LOWLANDS 126

3.5.1 Background 126
3.5.2 Assessment of Disposal Operations 133
3.5.3 Geotechnical and Hydrogeologic Considerations 140
3.5.4 Other Site Selection Considerations 140

3.5.4.1 Discussion 140
3.5.4.2 Ratings 140

3.5.5 Candidate and Back-Up Sites 140

3.6 REGION E: OZARK REGION 161

3.6.1 Background 161
3.6.2 Assessment of Disposal Operations 161

3.6.2.1 Categorization of Disposal Operations 161
3.6.2.2 Assessment of Disposal Operations 161

3.6.3 Geotechnical and Hydrogeologic Considerations 165
3.6.4 Other Site Selection Considerations 165
3.6.5 Candidate and Back-Up Sites 165

3.7 REGION F: GREAT LAKES REGION 169

Page(A-)

3.7.1 Background 169
3.7.2 Assessment of Disposal Operations 172

3.7.2.1 Categorization of Disposal Operations 172
3.7.2.2 Assessment of Disposal Operations 174
3.7.2.3 Comments on Handling and Transportation of Coal Ash 174

3.7.3 Geotechnical and Hydrogeologic Considerations 174
3.7.4 Other Site Selection Considerations 174

3.7.4.1 Discussion 174
3.7.4.2 Ratings 181

3.7.5 Candidate and Back-Up Sites 181

3.8 REGION G: SUPERIOR REGION 186

3.8.1 Background 186
3.8.2 Assessment of Disposal Operations 188

3.8.2.1 Categorization of Disposal Operations 188
3.8.2.2 Assessment of Disposal Operations 188
3.8.2.3 Comments on Handling and Transportation of FGC Wastes 191

3.8.3 Geotechnical and Hydrogeologic Considerations 191
3.8.4 Other Site Selection Considerations 191
3.8.5 Candidate and Back-Up Sites 191

3.9 REGION H-M: GREAT PLAINS AND WEST REGION 197

3.9.1 Background 197
3.9.2 Assessment of Disposal Operations 201

3.9.2.1 Categorization of Disposal Operations 201
3.9.2.2 Assessment of Disposal Operations 203
3.9.2.3 Comments on Handling and Transportation of FGC Wastes 203

3.9.3 Geotechnical and Hydrogeologic Considerations 203
3.9.4 Other Site Selection Considerations 212

3.9.4.1 Discussions 212
3.9.4.2 Ratings 213

3.9.5 Candidate and Back-Up Sites 213

4.0 CONCLUSIONS AND RECOMMENDATIONS 221

4.1 WASTE TYPE 221

Page(A-)

4.2 TYPE OF DISPOSAL 221
4.3 CLIMATIC AND GEOLOGIC CONDITIONS 222
4.4 FINAL RANKING 222

5.0 FINAL SELECTION 240

5.1 OVERAL BASIS 240
5.2 MID-COURSE EVALUATIONS 241

5.2.1 TVA 241
5.2.2 Mid-Course Consideration 242
5.2.3 Arid West 243
5.2.4 Small Planning 245

5.3 INDIVIDUAL VISITS 245
5.4 FINAL SELECTION 245

REFERENCES 238

EXHIBIT A

EXHIBIT B

EXHIBIT C

EXHIBIT D

LIST OF FIGURES

		Page (A-)
S.1	Location of Candidate & Back-up Sites	S-16 16
2.2	Site Selection Process Regions	12 12
2.5.1	Number of Coal-Fired Power Plants ≥ 200 Mw In Designated Regions of the United States	33
2.8.1	Mean Annual Cooling Degree Days	50
2.8.2	Mean Annual Heating Degree Days	51
2.8.3	Mean Annual Frost-Free Period	52
2.8.4	Areas with Significant Ground-Water Overdraft	54
2.8.5	Areas of Inadequate Surface Water Supply	55
A-1	Overall Project Information Flow Diagram	A-2
C-1	Geologic Map of the United States	C-2
C-2	Soil Deposits of the United States and Canada	C-3
C-3	Temperature Data Map	C-4
C-4	Maximum Depth of Frost Penetration (in inches) in the United States	C-5
C-5	Average Annual Precipitation (in inches) in the United States	C-6
C-6	Average Annual Lake Evaporation (in inches) in the United States	C-7
C-7	Normal Annual Runoff (in inches) in the United States	C-8

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

LIST OF TABLES

Page(A-)

S.1 Distribution of Coal-Fired Power Plants in the United States by State S-3

S.2 Current FGC Waste Disposal Methods Utilized at Utility Coal-Fired Power Plants in the United States S-4

S.3 Map Key for Location of Candidate and Back-Up Sites S-10

S.4 Recommended Candidate and Back-Up Sites - Overview S-11

S.5 Selected Sites S-15

2.2.1 Considerations Under RCRA 6

2.4.1 Summary of FGC Systems Expected to be in Commercial Operation on Utility Boilers in Late 1982 S-16

2.4.2 Potential Disposal Options S-18

2.4.3 Matrix of FGC Waste Disposal Methods Utilized at Utility Coal-Fired Power Plants ≥200 Mw in the United States S-19

2.4.4 Division of Utility Plants by Ash Handling Systems and Physiographic Region S-21

2.4.5 Projected Generation of Coal Ash and FGD wastes from Utility Boilers S-22

2.4.6 Projection of New Coal-Fired Utility Plants in the United States by Physiographic Region for the Period 1982-1990 S-25

2.4.7 Projection of New FGD Systems in the United States by Physiographic Region for the Period 1982-1990 S-26

2.4.8 Projection of New FGD Systems in the United States by Physiographic Region for the Period 1982-1990 S-27

2.4.9 Utility Plant Conversions from Oil/Gas to Coal by Physiographic Region S-29

2.5.1 Division of Utility Plants by Nameplate Generating Capacity and Physiographic Region S-31

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

LIST OF TABLES
Continued

Page (A-)

2.5.2 Division of Utility Plants by Nameplate Generating Capacity and Physiographic Region 31

2.5.3 Targeted Number of Candidate Sites from Each Region 35

2.6.1 Assessment of Disposal Operations 38

2.7.1 Hydrogeologic Ranking System for Candidate Site Selection 42

2.8.1 Other Site Selection Ratings for Disposal Sites 58

3.1.1 Preliminary Listingof Potential Power Plant Sites in Gulf Coastal Plain Region (A1) of the U.S. 62

3.1.2 Matrix of FGC Waste Disposal Methods Utilized Coal-Fired Power Plants >200 Mw in the Gulf Coastal Region (A1) of the U.S. 65

3.1.3 Assessment of Disposal Operations in Gulf Coastal Plain Region (A1) of the U.S. 67

3.1.4 Geotechnical/Hydrogeologic Rating of Sites - Region A1 69

3.1.5 Other Site Selection Ratings for Disposal Operations in the Gulf Coastal Plain Region (Region A-1) 72

3.1.6 Recommended Candidate and Back-Up Sites - Gulf Coastal Plain - Region A1 75

3.2.1 Preliminary Listing of Potential Power Plant Sites in Piedmont & Coastal Plain Region (A2) of the U.S. 77

3.2.2 Matrix of FGC Waste Disposal Methods Utilized at Utility Coal-Fired Power Plants >200 Mw in the Piedmont and Coastal Plain Region (A2) of the U.S. 79

3.2.3 Assessment of Disposal Operations in Gulf Coastal Plain Region (A2) of the U.S. 81

3.2.4 Geotechnical/Hydrogeologic Rating of Sites - Region A2 82

For Page Numbering

LIST OF TABLES
Continued

		Page(A-)
3.2.5	Other Site Selection Ratings for Disposal Operations in the Piedmont Region (A2)	87
3.2.6	Recommended Candidate and Back-Up Sites - Piedmont and Coastal Plain - Region A2	90
3.3.1	Preliminary Listing of Potential Power Plant Sites in Appalachian Region (B) of the U.S.	93
3.3.2	Matrix of FGC Waste Disposal Methods Utilized at Utility Coal-Fired Power Plants >200 Mw in the Appalachian Region (B) of the U.S.	96
3.3.3	Assessment of Disposal Operations in Appalachian Region (B) of the U.S.	99
3.3.4	Geotechnical/Hydrogeologic Rating of Sites - Region B	102
3.3.5	Other Site Selection Ratings for Disposal Operations in the Appalachian Region (Region B)	112
3.3.6	Recommended Candidate and Back-Up Sites - Appalachian Region - Region B	120
3.4.1	Preliminary Listing of Potential Power Plant Sites in New England Region (C) of the U.S.	124
3.4.2	Matrix of FGC Waste Disposal Methods Utilized at Utility Coal-Fired Power Plants >200 Mw in the New England Region (C) of the U.S.	125
3.4.3	Assessment of Disposal Operations in New England Region (C) of the U.S.	127
3.4.4	Geotechnical/Hydrogeologic Rating of Sites - Region C	128
3.4.5	Other Site Selection Ratings for Disposal Operations in in the New England Region (Region C)	129
3.5.1	Preliminary Listing of Potential Power Plant Sites in Interior Lowlands Region (D) of the U.S.	130
3.5.2	Matrix of FGC Waste Disposal Methods Utilized at Utility Coal-Fired Power Plants >200 Mw in the Interior Lowlands Region (D) of the U.S.	134

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

LIST OF TABLES
Continued

Page(A-)

3.5.3 Assessment of Disposal Operations in Interior Lowlands Region (D) of the U.S. 137 137

3.5.4 Geotechnical/Hydrogeologic Rating of Sites - Region D 141 141

3.5.5 Other Site Selection Ratings for Disposal Operations in the Interior Lowlands Region (Region D) 152 152

3.5.6 Recommended Candidate and Back-Up Sites - Appalachian Region - Region D 159 159

3.6.1 Preliminary Listing of Potential Power Plant Sites in Ozark Region (E) of the U.S. 162 162

3.6.2 Matrix of FGD Waste Disposal Methods Utilized at Utility Coal-Fired Power Plants >200 Mw in the Ozark Region (E) of the U.S. 163 163

3.6.3 Assessment of Disposal Operations in Ozark Region (E) of the U.S. 164 164

3.6.4 Geotechnical/Hydrogeologic Rating of Sites - Region E 166 166

3.6.5 Other Site Selection Ratings for Disposal Operations in the Ozark Region (Region E) 167 167

3.6.6 Recommended Candidate Site - Region E - Ozarks 168 168

3.7.1 Preliminary Listing of Potential Power Plant Sites in Great Lakes Region (F) of the U.S. 170 170

3.7.2 Matrix of FGC Waste Disposal Methods Utilized at Utility Coal-Fired Power Plants >200 Mw in the Great Lakes Region (F) of the U.S. 173 173

3.7.3 Assessment of Disposal Operations in Great Lakes Region (F) of the U.S. 175 175

3.7.4 Geotechnical/Hydrogeologic Rating of Sites - Region F 176 176

3.7.5 Other Site Selection Ratings for Disposal Operations in the Great Lakes Region (Region F) 182 182

3.7.6 Recommended Candidate and Back-Up Sites - Great Lakes - Region F 185 185

10 Lines to End of Typing Area

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

LIST OF TABLES
Continued

		Page (A-)	
3.8.1	Preliminary Listing of Potential Power Plant Sites in Superior Region (G) of the U.S.	187	187
3.8.2	Matrix of FGC Waste Disposal Methods Utilized at Utility Coal-Fired Power Plants >200 Mw in the Superior Region (G) of the U.S.	189	189
3.8.3	Assessment of Disposal Operations in the Superior Region (G) of the U.S.	190	190
3.8.4	Geotechnical/Hydrogeologic Rating of Sites - Region G	192	192
3.8.5	Other Site Selection Ratings for Disposal Operations in the Superior Region (Region G)	194	194
3.8.6	Recommended Candidate and Back-Up Sites - Superior - Region G	196	196
3.9.1	Preliminary Listong of Potential Power Plant Sites in Great Plains and West Regions (H through M) of the U.S.	198	198
3.9.2	Matrix of FGC Waste Disposal Methods Utilized at Utility Coal-Fired Power Plants ≥200 Mw in the Great Plains and West Regions (H-M) of the U.S.	202	202
3.9.3	Assessment of Disposal Operations in Great Plains and West Region (H-M) of the U.S.	204	204
3.9.4	Geotechnical/Hydrogeologic Rating of Sites - Region H-M	206	206
3.9.5	Other Site Selection Ratings for Disposal Operations in the Great Plains and West Regions of the U.S. (Regions H-M)	214	214
3.9.6	Recommended Candidate and Back-Up Sites - Great Plains and the West - Regions H-M	219	219
4.1	Recommended Candidate and Back-Up Sites - All Regions	223	223
4.2	Final Twenty-Six Sites	227	227
4.3	Recommended Candidate and Back-Up Sites	230	230

10 Lines to End of Typing Area

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

LIST OF TABLES
Continued

		Page (A-)
4.4	List of Candidate and Back-Up Sites	232
4.5	Categorization of Recommended Candidate and Back-Up Sites	235
5.1	Division of Candidate and Back-Up Sites by Sulfur Rank, Particulate Collection, and Sulfur Control Systems	244
5.2	Individual Disposal Site Visits - Candidate and Back-Up Sites	246
5.3	Other Site Visits - Midcourse Additions	250

USE THIS SHEET FOR REPORT TYPING [illegible]

TOP

PARTICIPANTS IN THE STUDY

This Site Selection Report is submitted by Arthur D. Little, Inc. to the U. S. Environmental Protection Agency under Contract No. 68-02-3167. The report reflects the work of many members of the Arthur D. Little, Inc. staff and its subcontractors. Those participating in this study are listed below.

Principal Investigators

Chakra J. Santhanam	Arthur D. Little, Inc., Project Manager
Charles B. Cooper	Arthur D. Little, Inc.
Armand A. Balasco	Arthur D. Little, Inc.
David E. Kleinschmidt	Arthur D. Little, Inc.

Contributing Staff

Richard R. Lunt	Arthur D. Little, Inc.
John F. Peirson	Arthur D. Little, Inc.
Sara E. Bysshe	Arthur D. Little, Inc.
Kathryn A. Saterson	Arthur D. Little, Inc.
Anne B. Littlefield	Arthur D. Little, Inc.
Barbara A. Kuryk	Arthur D. Little, Inc.
William A. Tucker	Arthur D. Little, Inc.
Itamar Bodek	Arthur D. Little, Inc.
James R. Valentine	Arthur D. Little, Inc.
James E. Oberholtzer	Arthur D. Little, Inc.

Subcontractors

Haley & Aldrich	John Humphrey Allen Hatheway Zenas Bliss James Kennedy
University of Louisville	D. Joseph Hagerty C. Robert Ullrich
Bowser-Morner Testing Laboratories	Barry Thacker David Cowhered

We are indebted to Penelope Hanson and John Heffelfinger of the EPA, Office of Solid Waste, Hazardous Waste Division, for their involvement and guidance throughout the course of this effort.

Above all, we thank Julian W. Jones, the EPA Project Officer, for his guidance throughout the course of this work and in the preparation of this report.

EXECUTIVE SUMMARY

This report is submitted by Arthur D. Little, Inc. (ADL) under EPA Contract 68-02-3167. This contract with the Environmental Protection Agency (EPA) requires ADL to conduct a study of current coal ash and flue gas desulfurization waste disposal practices at coal-fired power plants. This study involves environmental monitoring, data gathering, and economic assessments of disposal practices at six selected sites at various locations around the country. Results of the study will provide the technical background data and information needed to determine the degree to which disposal of these wastes needs to be managed in order to protect human health and the environment. It is anticipated that EPA will ultimately issue to state and local permitting officials guidance for environmentally sound management and disposal of coal ash and FGD wastes.

The first step in this project involved the evaluation of available information on coal-fired power plants to develop a preliminary list of candidate and back-up sites. These sites were then evaluated in greater detail leading to the final selection of six sites for detailed waste characterization and monitoring can be made. This report describes the evaluation processes that led to the selection of the six sites that were studied in 1981 and 1982.

This report makes use of available baseline information including the precursor study(1) to this project for the EPA. Taking into account the mix of waste types and disposal methods and the range of environmental and hydrogeologic conditions, a group of 18 candidate sites and eight back-up sites were recommended. These were then studied in greater detail including field visits. During this process, mid-course additions of potentially viable sites were made and then were also evaluated leading to the final selection of the six (6) sites.

Technology and Production of Wastes

Coal-fired utility boilers generate two types of coal ash: fly ash and bottom ash. Fly ash is collected by mechanical collectors, electrostatic precipitators, fabric filters, or wet scrubbers. Flue gas desulfurization (FGD) can be accomplished by nonregenerable or throwaway systems which result in FGD wastes and regenerable systems which primarily produce a saleable produce (sulfur or sulfuric acid). As of late 1982, approximately 33.400 Mw (equivalent scrubbed capacity) of coal-fired utility boilers employ flue gas desulfurization systems(7); 90% of these use nonregenerable systems. Nonregenerable systems currently employ wet scrubbing technology although some dry scrubbing systems became operational in 1982. The principal types of systems used in utility power plants are those based on direct limestone, direct lime, alkaline fly ash, and dual alkali.

The quantities of coal ash and FGD wastes (together comprising flue gas cleaning or FGC wastes) depend on the ash and sulfur content of the coal, emission regulations, the types of ash collection and FGD systems, and operating conditions of the systems and boiler. To meet New Source Performance Standards (NSPS), a typical utility operating at 70% load produces 100 to 500 metric tons (110 to 550 tons) of dry, ash-free FGD sludge and 200 to 600 metric tons (220 to 660 tons) of coal ash annually per megawatt of capacity.

Number of Coal-Fired Utility Plants

As of 1977, there were more than 340 steam electric plants in the United States utilizing coal for 80% or more of their power generation and with nameplate capacity greater than 25 Mw. Table S.1 presents data on steam electric plants using coal as their primary fuel. During the period of 1982-1990 and additional 122 new coal-fired plants with a total generating capacity of above 83,400 Mw are anticipated. In addition, a number of plants are likely to be converted to coal from other fossil fuels (oil and gas). The development of baseline data under this project takes cognizance of both current and anticipated future use of coal.

Disposal vs. Utilization Options

Over the longer term, an effective way to manage the flue gas cleaning (FGC) wastes is to utilize coal ash and FGD wastes. There is some utilization of coal ash. At present, however, most of the coal ash and FGD wastes generated are sent to disposal. Considering the expected increase in coal utilization in boilers in the United States, this is likely to be the case for many years. Utilization is expected to grow but at a slower rate than FGC waste generation.

Currently, all FGC wastes are disposed of on land. Ocean disposal may be a future alternative if it can be practiced under environmentally acceptable conditions. The principal methods of disposal are:

- ponding;
- landfilling, including mine disposal which may be considered a special subcategory of landfilling; and
- interim ponding followed by landfilling.

Table S.2 presents data on current disposal practices.

Ponding is a more widely used disposal practice than any other on a national basis today. Ponds can be designed based on diking or incision and can even be engineered on slopes, but the construction of dikes or other means of containment for ponds is usually expensive. In the past few years landfilling has become a growing practice. Typically in landfilling the wastes are dewatered to a moist soil-type material and transported to the disposal site where they are spread on the

Table S.1

DISTRIBUTION OF COAL-FIRED POWER PLANTS[a] IN THE U.S. BY STATE

State	Number of Plants			Total Capacity (Mw)	
	With FGD	Without FGD	Total	Nameplate Generating	FGD Scrubbed
Alabama	2	5	7	9,818	908
Arizona	2	1	3	3,343	859
Arkansas	0	0	0	0	0
California	0	0	0	0	0
Colorado	0	5	5	2,576	0
Connecticut	0	0	0	0	0
Delaware	0	1	1	340	0
Florida	0	3	3	2,905	0
Georgia	0	7	7	9,451	0
Idaho	0	0	0	0	0
Illinois	4	15	19	16,376	1,384
Indiana	3	15	18	13,634	912
Iowa	0	4	4	1,806	0
Kansas	3	0	3	2,891	1,959
Kentucky	5	9	14	11,570	1,264
Louisiana	0	0	0	0	0
Maine	0	0	0	0	0
Maryland	0	1	1	586	0
Massachusetts	0	0	0	0	0
Michigan	0	11	11	9,804	0
Minnesota	1	5	6	3,800	1,440
Mississippi	1	0	1	360	248
Missouri	2	9	11	9,815	374
Montana	1	0	1	720	720
Nebraska	0	2	2	872	0
Nevada	1	1	2	1,976	340
New Hampshire	0	1	1	459	0
New Jersey	0	1	1	652	0
New Mexico	1	1	2	2,980	711
New York	0	4	4	1,978	0
North Carolina	0	12	12	10,981	0
North Dakota	2	1	3	1,879	732
Ohio	1	19	20	22,211	822
Oklahoma	0	0	0	0	0
Oregon	0	0	0	0	0
Pennsylvania	4	15	19	18,657	2,874
Rhode Island	0	0	0	0	0
South Carolina	1	7	8	3,429	140
South Dakota	0	1	1	440	0
Tennessee	0	8	8	10,089	0
Texas	2	4	6	6,070	2,585
Utah	2	0	2	1,105	726
Vermont	0	0	0	0	0
Virginia	0	4	4	1,817	0
Washington	0	1	1	1,329	0
West Virginia	1	10	11	12,120	519
Wisconsin	0	8	8	4,336	0
Wyoming	0	3	3	2,982	0
TOTALS	39	194	233	206,157	19,517

---

[a] Coal-fired plants with ≥80% of power generated from coal in 1977 and capacities ≥200 Mw with exceptions for plants employing an FGD system.

Source: Compiled by Arthur D. Little, Inc. based on References (7,20).

Table S.2

CURRENT FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS IN THE UNITED STATES

(Data Base: 176 Plants ≥ 200 Mw)[a]

Type of Waste	Number of Plants		
	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	18	46	6
Bottom ash only	29	13	29
Combined fly and bottom ash	69	9	16
FGD waste only	5	-	-
Mixed fly ash and FGD waste	7	7	-
Mixed bottom ash and FGD waste	1	-	1
Mixed fly ash and FGD waste (stabilized)	2	6	-
Mixed fly ash, bottom ash, and FGD waste	2	1	1

---

[a] Coal-fired plants on which data was available (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal.

Source: Compiled by Arthur D. Little, Inc. based on Actual Utility Plant Data Survey Sheets used in developing the report(1).

USE THIS SHEET FOR REPORT TYPING 8 1/2 x 11

TOP

ground in about 0.3 to-one-meter (one-to-three-foot) heights and compacted. Layering proceeds and ultimately fill may be about 8 to 25 meters (25 to 80 feet) or more in height. Interim ponding/landfilling is a hybrid involving ponding at first followed by landfilling of the dredged solids.

In the past, utilities operating FGC systems (coal ash and FGD wastes) have typically disposed of wastes by storage in ponds. However, several factors will increase the sources and total volume of waste and influence disposal options in the coming years.

- An increase in coal-fired capacity in the United States. In 1979, the total U.S. coal-fired electric utility generating capacity was estimated at over 235,000 Mw in 395 plants.(13) The estimated capacity is expected to increase by 1990 to over 343,000 Mw.(14)

- A major increase in the application of scrubber technology by utilities and a consequent increase in FGD waste generation. At present over 33,000 Mw of equivalent scrubbed capacity at 56 plants utilize FGD systems. As of late 1982, over 100,000 Mw of equivalent scrubbed capacity have been installed or committed to FGD systems.(7)

- Advances in stabilized technology for FGD wastes which permit landfill disposal of partially dewatered solids instead of ponding sludges that are difficult to handle. In the future, disposal of wastes in managed fills is likely to be encouraged.

- Environmental regulatory developments including the Clean Air Act of 1977 and the Resource Conservation & Recovery Act of 1976 (RCRA). New Source Performance Standards (NSPS) for criteria pollutants were issued in June 1979.(9)

It is expected that the regulations for disposal of non-hazardous wastes developed by individual states under RCRA authorization will increasingly affect the selection of disposal sites and practices by individual utilities.

- Energy-related regulatory developments under the Energy Supply and Environmental Coordination Act (ESECA) of 1974, the Power Plant and Industrial Fuel Use Act (FUA) of 1978 and the Omnibus Reconciliation Act (OBRA) of 1981. Several plants are converting to coal(19) from other fossil fuels (oil, gas).

Candidate Site Selection Process

The overall objective of the candidate site selection process is to evaluate available data on coal-fired power plants and recommend a number of candidate and back-up sites. It was decided that 18 candidate sites would be recommended providing a pool of 50% greater than the final 12 sites required. In addition, a smaller but unspecified number of back-up sites would be recommended.

The environmental impact of FGC waste disposal and, hence, any potential threat to human health and evironment is influenced by three factors:

- type of waste generated,
- disposal method employed, and
- disposal site characteristics (soil type, hydrogeology, climate, etc.)

During the candidate site selection process, a mix of waste types, modes of disposal, and site characteristics was considered.

The selection of candidate sites together with back-up sites was the result of a two-step process.

- First, the contiguous 48 states were divided into 14 physiographic regions, and the plants in each region were screened to develop a list of plants that could be suitable for consideration as candidate and back-up sites. It was agreed that the total number of candidate sites would be 18 providing 50% redundancy. In addition a smaller number of back-up sites was considered desirable. A total target of 25 to 30 sites including back-up sites was desired. Based on an assessment of present and future FGC waste disposal, a preliminary distribution of the targeted number of candidate sites in each region was agreed upon. In screening selections, the investigators remained cognizant of the targeted number in each region but were not absolutely limited by that number. The attempt was to choose desirable plants in as many regions as possible. The list of plants in all the regions that came through this filtration process amounted to about 26.
- Second, these 26 were then ranked in iterative group discussions leading to the nomination of 18 as candidate sites and the remainder as back-up sites.

Initial Screening for Sites

The initial screening process consisted of the following steps:

- Definition of overall study objectives. The overall objective was to select sites that would include the prevalent methods of disposal used by industry today and those with future potential. For example, it appears that in the future dry disposal of FGC wastes (that is, as moist soil-like materials) in managed fills is likely to be encouraged. Similarly, use of coal in western plants is likely to grow. Factors like the above were recognizable in defining required characteristics of suitable sites.

In defining study objectives it is well to note that the focus of this study would be those subject areas that are priority concerns under RCRA for utility solid waste disposal. These are:

- impact on groundwater quality,
- impact on surface water quality from non-point sources, and
- use of mitigative design, control, or management practices.

The subsequent criteria for selection were based on the need to study impacts in the above subject areas.

- Development of appropriate engineering/technology related screening criteria to assess a plant's disposal operations. Engineering/technology criteria included factors related to waste variability, site age, FGD system, and application of mitigative engineering practices. These were applied as the first level screens.
- Development of hydrogeologic criteria. The hydrogeologic constraints related to bedrock geology, surficial soil characteristics, groundwater flow conditions at the site, and climate. The attempt was to select sites where data from about one year of environmental monitoring can be used for assessment with reasonable confidence.
- Development of other site selection criteria taking into account overall objectives of RCRA. The approach was to mainly focus on factors relating to impacts on groundwater and non-point source impacts on surface water, and application of mitigative measures. The rating factors fall into two basic categories. This has been presented in the report in two stages:
  - a narrative description of important factors concerning the site for use by the ADL Team; and
  - a rating system outlining potential opportunities to study effects.

Regional/general factors, such as climate, regional soils, and critical regions for groundwater and surface water utilization were considered. Then site-specific factors were evaluated, such as site setting (substrate and proximity to surface water), mitigative controls, complicating factors (such as other external influents to an ash pond), availability of baseline environmental information, and other study opportunities. It is important to emphasize that the

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

factors used only illustrated potential opportunities to study various types of environmental impacts. No attempt was made to prefer sites with high or low actual impacts.

The above three screening criteria (engineering/technologic, other site selection factors, and hydrogeologic) were used to obtain a preliminary list of sites where reasonable assessment of data obtained from about one year of monitoring would be possible. The approach was to focus on sites where cost-effective data gathering and reliable assessment of data was possible. The overall objective of this project is to provide the information necessary to develop reasonable guidelines for all kinds of disposal sites, including very complex ones. However, for the research phase of this effort, it is necessary to select sites where data from one year of monitoring can be used for reliable assessment. Therefore, very complex sites where reliable data interpretation is not possible (on technological or hydrogeologic grounds) were eliminated from further consideration. However, the overall plan for characterization and environmental monitoring at the final 12 sites will be designed to permit development of assessment and recommendations applicable to complex sites, complex waste types, and complex methods of disposal.

Ranking Leading to Candidate and Back-Up Sites

The investigators evaluated the initial list of sites in an iterative manner taking into account three categories of variables:

- Waste Type: An analysis of the available information indicated that the disposal of six categories of wastes constitute the vast majority: fly ash disposal, bottom ash disposal, combined fly and bottom ash disposal, disposal of FGD waste alone, FGD waste and fly ash co-disposal, and stabilized FGD waste disposal. These combinations are likely to remain the only major options of importance in the future.

- Method of Disposal: Ponding and landfill-type operations are practicable for many wastes. However, stabilized FGD waste disposal as moist soil-like materials in landfills is likely to be very important. Similarly, FGD wastes, when disposed of alone, are usually disposed of by ponding only. In the future, with forced oxidation methods, FGD waste disposal by itself in the form of gypsum stacks may be practical; however, such disposal practices do not exist on full scale at present. Hence, FGD waste disposal by ponding alone was considered. Similarly, mine disposal is a special subcategory of landfill-type disposal and was considered when appropriate.

10 Lines to End of Typing Area

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

- General Location: While the initial screening was done on the basis of 14 physiographic regions, the final ranking was based on dividing the United States into three environmental zones: Coastal, Interior, and West. Plants within a few miles of Atlantic and Gulf coasts were grouped as Coastal plants. Plants in or west of Montana, Wyoming, Colorado, and New Mexico were considered Western plants. The remainder of the contiguous 48 states were considered Interior.

The ranking process began by listing all sites with a particular mix of waste type, method of disposal (e.g., fly ash ponding) and general location. The sites were relative to each other and the more promising ones were recommended as candidate sites, and the others as backups. In some cases, backups were not available and in some other cases back-ups were in different regions. Collectively the back-up sites provide the capability to measure effects if some of the candidates are found unsuitable.

The recommended candidate and back-up sites are listed in Table S.3. Table S.4 provides categorization of the recommended candidate and back-up sites by waste type/disposal mode and region. It may be noted that for many disposal modes there are no candidate or back-up sites in some regions of the country. This is usually because such practice is either not very common in that particular region or not employed at all. For example, separate fly ash ponding in the Coastal zone has no candidates as this practice is not employed in the Coastal zone. Similarly, the separate landfilling of fly ash in the Coastal zone has no candidate as this is an atypical practice in this region.

Table S.3

MAP KEY FOR LOCATION OF CANDIDATE AND BACK-UP SITES

Map Number	Plant Name	Utility Name	County	State
1	Allen	Duke Power	Gaston	NC
2	Arapahoe	Public Service of Colorado	Denver	CO
3	Big Brown (Back-up)	Texas Power & Light	Freestone	TX
4	Jim Bridger (Back-up)	Pacific Power & Light	Sweetwater	WY
5	Clifty Creek	Indiana-Kentucky Electric	Jefferson	IN
6	Colstrip	Montana Power	Rosebud	MT
7	Columbia I	Wisconsin Power & Light	Portage	WI
8	Comanche (Back-up)	Public Service of Colorado	Pueblo	CO
9	Drake	Colorado Springs Dept. Pub. U.	El Paso	CO
10	Duck Creek (Back-up)	Central Illinois Light	Fulton	IL
11	Elrama	Duquesne Light	Washington	PA
12	Huntley (Back-up)	Niagara Mohawk Power	Erie	NY
13	Dave Johnston	Pacific Power & Light	Converse	WY
14	Keystone	Pennsylvania Electric	Armstrong	PA
15	A.S. King	Northern States Power	Washington	MN
16	George Neal (Back-up)	Iowa Public Service	Woodbury	IA
17	Powerton	Commonwealth Edison	Tazewell	IL
18	Presque Isle	Upper Peninsula Generating	Marquette	MI
19	Sherburne County	Northern States Power	Sherburne	MN
20	Smith	Gulf Power	Bay	FL
21	Southwest	Springfield City Utilities	Greene	MO
22	Sporn (Back-up)	Central Operating	Mason	WV
23	Sutton (Back-up)	Carolina Power & Light	New Hanover	NC
24	Tombigbee	Alabama Electric Coop.	Washington	AL
25	Widows Creek	Tennessee Valley Auth.	Jackson	AL
26	Winyah	S. Carolina Public Ser. Auth.	Georgetown	SC

Table S-4

RECOMMENDED CANDIDATE AND BACK-UP SITES - OVERVIEW

No.	Plant Name	Utility Name	Location		Nameplate Generating Capacity (Mw)	Start-up Date^a	Disposal	Region
			County	State				
	CANDIDATE SITES							
1	Allen	Duke Power	Gaston	NC	1155	-/57	Combined fly and bottom ash to an unlined pond.	Interior
2	Arapahoe	Public Service of Colorado	Denver	CO	250	-/50	Combined fly and bottom ash to an interim pond and then to a landfill.	West
3	Clifty Creek	Indiana-Kentucky Electric	Jefferson	IN	1303	2/55	Fly and bottom ash to separate clay substrate lined ponds.	Interior
4	Colstrip	Montana Power	Rosebud	MT	720 (720 on FGD)	11/75	Fly ash/FGD wastes to a clay substrate lined interim pond and then to an unlined final pond. Bottom ash to separate clay substrate lined pond interim pond and then to the same final pond.	West
5	Columbia I	Wisconsin Power & Light	Portage	WI	556	5/75	Fly and bottom ash to separate unlined ponds.	Interior
6	Drake	Colorado Springs Dept. of Public Utilities	El Paso	CO	282	-/62	Combined fly and bottom ash to a clay substrate lined landfill.	West
7	Elrama	Duquesne Light & IU Conversion Systems	Washington	PA	510 (510 on FGD	6/52 FGD in 10/75	FGD wastes stabilized and disposed in an off-site landfill. Combined fly and bottom ash to an unlined interim pond and then to the same landfill.	Interior
8	Dave Johnston	Pacific Power & Light	Converse	WY	750	-59	Fly ash to an unlined landfill. Combined fly and bottom ash to a clay substrate lined interim pond and then to the same landfill. Bottom ash to an unlined interim pond and then to the same landfill.	West
9	Keystone	Pennsylvania Electric	Armstrong	PA	1872	1/67	Fly ash to an unlined landfill. Bottom to an unlined interim pond and then to the same landfill.	Interior
10	A. S. King	Northern States Power	Washington	MN	598	-/68	Combined fly and bottom ash to an unlined landfill.	Interior

Table S-4 (Continued)

RECOMMENDED CANDIDATE AND BACK-UP SITES - OVERVIEW

No.	Plant Name	Utility Name	Location		Nameplate Generating Capacity (Mw)	Start-up Date[a]	Disposal	Region
			County	State				
11	Powerton	Commonwealth Edison	Tazewell	IL	1785	-/72	Fly ash to an artificially lined landfill. Bottom ash to the same landfill. Landfill is off-site.	Interior
12	Presque Isle	Upper Peninsula Generating	Marquette	MI	301	9/55	Fly ash to an unlined landfill. Bottom ash to an unlined interim pond and then to the same landfill.	Interior
13	Sherburne County	Northern States Power	Sherburne	MN	1440 (1440 on FGD)	5/76	Fly ash/FGD wastes to a clay substrate lined pond. Bottom ash to an interim pond and then sold.	Interior
14	Smith	Gulf Power	Bay	FL	340	6/65	Combined fly and bottom ash to an unlined pond.	Coastal
15	Southwest	Springfield City	Greene	MO	194 (194 on FGD)	6/76 FGD in 4/77	Fly ash/FGD wastes to an artificially lined landfill. Bottom ash to an artifically lined interim pond and then to the same landfill.	Interior
16	Tombigbee	Alabama Electric Coop.	Washington	AL	585 (385 on FGD)	6/69 FGD in 9/78	FGD wastes to a lined pond.	
17	Widows Creek	Tennessee Valley Authority	Jackson	AL	1977 (550 on FGD)	7/52 FGD in 1/78	FGD wastes to an unlined pond. Combined fly and bottom ash to an unlined pond.	Interior
18	Winyah	South Carolina Public Service Authority	Georgetown	SC	630 (140 on FGD)	5/75 FGD in 7/77	FGD wastes to an unlined pond. Combined fly and bottom ash probably ponded.	Coastal
	BACK-UP SITES							
19	Big Brown	Texas Power & Light	Freestone	TX	1186	12/71	Fly ash to a clay substrate lined landfill. Bottom ash to clay substrate lined pond.	Interior
20	Jim Bridger	Pacific Power & Light	Sweetwater	WY	1525	9/74	Combined fly and bottom ash to a landfill which is a mine.	Interior

Table S-4 (Continued)

RECOMMENDED CANDIDATE AND BACK-UP SITES - OVERVIEW

No.	Plant Name	Utility Name	Location		Nameplate Generating Capacity (Mw)	Start-up Date[a]	Disposal	Region
			County	State				
21	Comanche	Public Service of Colorado	Pueblo	CO	778	-/73	Fly ash to a landfill. Bottom ash to an interim pond and then to the same landfill.	West
22	Duck Creek	Central Illinois Light	Fulton	IL	441 (416 on FGD)	6/76 FGD in 9/76	Fly ash/FGD wastes to an unlined pond. Bottom ash to an unlined pond.	Interior
23	Huntley	Niagara Mohawk Power	Erie	NY	828	-/42	Fly ash to an unlined landfill. Bottom ash to unlined and lined interim ponds and then to the same landfill.	Interior
24	George Neal	Iowa Public Service	Woodbury	IA	961	-/64	Combined fly and bottom ash to an unlined pond.	Interior
25	Sporn	Central Operating	Mason	WV	1105	-/50	Fly ash to an unlined pond. Bottom ash to an unlined interim pond and then sold.	Interior
26	Sutton	Carolina Power & Light	New Hanover	NC	671	8/54	Combined fly and bottom ash to an unlined pond.	Coastal

---

[a] Original start-up date of plants first coal-fired unit.

Final Selection Process

The candidate and back-up sites listed above were then subjected to a more detailed evaluation. These evaluations included one or more detailed site visits by appropriate engineering, environmental and hydrogeologic specialists from the investigative team. Their findings together with mid-course evaluations that were continuously taking place led to an iterative and effective site selection process that resulted in the final six sites.

Important elements of individual evaluations and investigative processes that comprised the final site selection were:

- Mid-course evaluations were always underway concerning the distribution of the sites with reference to coal rank, particularly coal systems and sulfur controls. On balance, given the budget constraints, the effort has resulted in a reasonable mix of these features.
- Specific evaluations were undertaken of individual sites from major participating utilities, notably TVA.
- It was the desire of the utility industry that a site west of the Continental Divide, in the relatively arid part of the country, be included. Specific efforts were added to the site selection process to include another western site. Ultimately Apache Plant of Arizona Electric Power Cooperative was nominated as an added seventh site. However, budget and time constraints combined to prevent the site from being evaluated.
- It was pointed out by industry representatives that the engineering/cost impacts of coal ash and FGD waste disposal at small plants (less than 100 Mw) could be substantially different from the impacts at the larger plants. Strong efforts in conjunction with the industry were also added to the site selection process to locate a suitable small plant for study. Unfortunately many of the smaller plants practiced disposal of these wastes along with other types of wastes which are outside the scope of our study. Hence, no suitable small plant was available for this project.

The above processes during 1980 and 1981 led to the selection of final sites. Table S.5 provides overall information on the final six sites that were selected for evaluations under this project. All of these sites were developed during 1981. Figure S.1 indicates the locations of these sites.

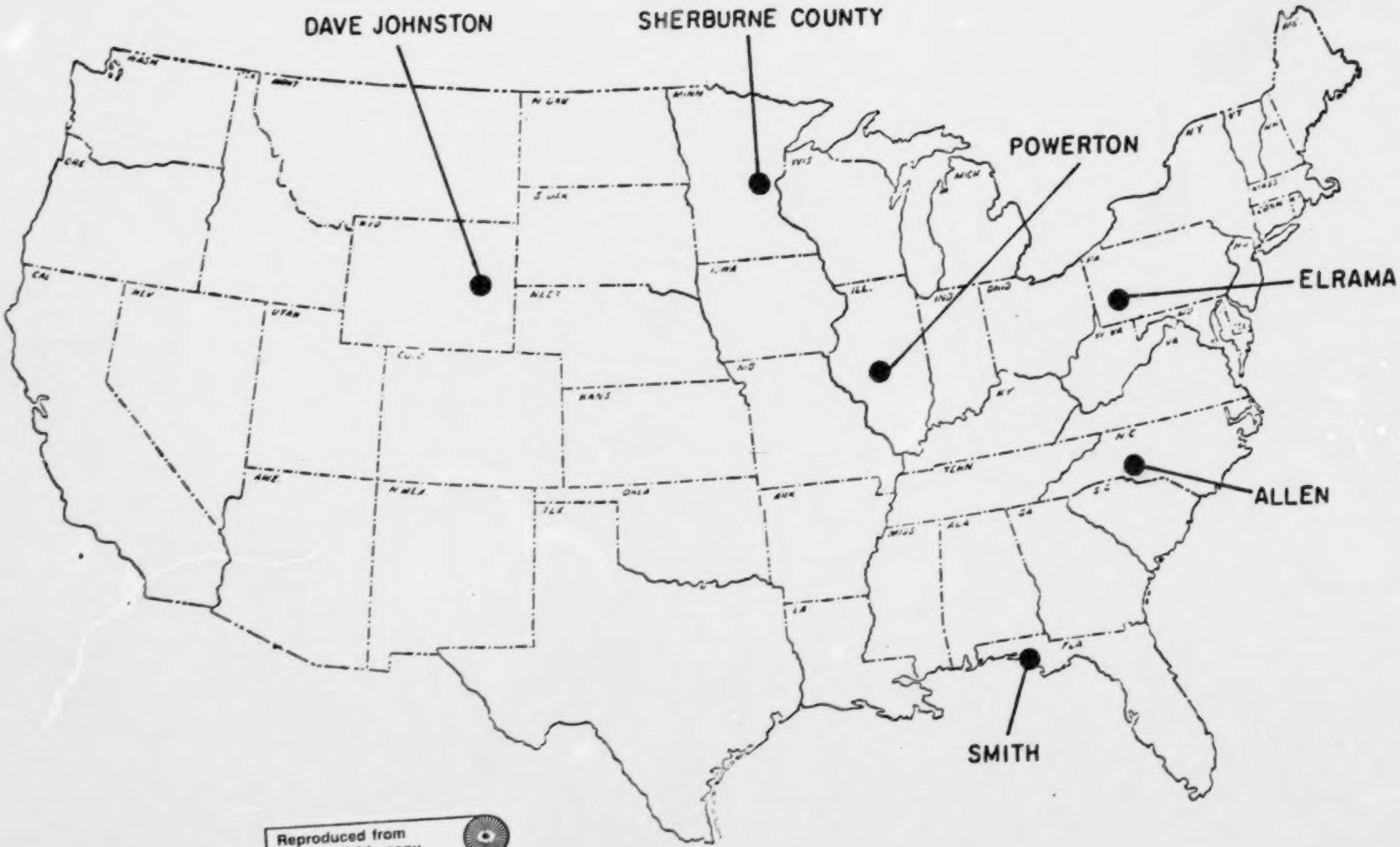
TABLE S.5 SELECTED SITES

		Location		Capacity (MW)		Startup Date (mo/yr)		Waste Site Under Study		High Priority Issues Under Study		
Plant	Utility	State	County	Nameplate Generating	FGD Unit On	Plant	FGD	Waste Type	Disposal Method	Ground-water Quality	Surface Water Quality	Employment of a Potentially Mitigative Practice
Allen	Duke Power	NC	Gaston	1155	-	-/57	-	Combined fly and bottom ash	Pond (UL)	X	X	X
Elrama	Duquesne Light & Conversion Systems, Inc.	PA	Washington	510	510	6/52	10/75	Stabilized FGD waste Combined fly and bottom ash	Landfill (UL; offsite) Landfill (UL; offsite)	X	X	X
Dave Johnston	Pacific Power & Light	WY	Converse	750	-	-/59	-	Fly ash	Landfill (UL)	X	-	X
Sherburne County	Northern States Power	MN	Sherburne	1458	1458	5/76	5/76	Fly ash/FGD	Pond (AL)	X	-	X
Powerton	Commonwealth Edison	IL	Tazewell	1786	-	-/72	-	Combined fly and bottom ash	Landfill (AL)	X	X	X
Smith	Gulf Power	FL	Bay	340	-	6/65	-	Combined fly and bottom ash	Pond (UL)	X	X	X

UL - Unlined

AL - Artificially Lined

From FGD 5/82 Paper


DAVE JOHNSTON
SHERBURNE COUNTY
POWERTON
ELRAMA
ALLEN
SMITH

Reproduced from best available copy.

From NAA 2/82 Paper

FIGURE S.1

SELECTED SITES FOR EVALUATIONS

1.0 INTRODUCTION

In October 1979, the U.S. Environmental Protection Agency (EPA) initiated a project under EPA Contract No. 68-02-3167, entitled "Characterization and Environmental Monitoring of Full-Scale Utility Waste Disposal Sites." The purpose of this overall project is to obtain sufficient data and information to assist the EPA in determining the extent, if any, to which these wastes (coal ash and FGD wastes) need to be managed to protect human health and the environment under the Resource Conservation and Recovery Act (RCRA). Exhibit A briefly outlines the scope of the project and the principal participating organizations.

The project has been divided into four areas of endeavor:

1. Site selection or the identification of sites for detailed environmental monitoring. This effort consists of engineering, environmental, and hydrogeologic evaluation of sites and identification of candidate and back-up sites from which 6 sites will be selected for detailed characterization and monitoring.

2. Development of the 6 disposal sites for detailed environmental monitoring.

3. Sampling and analysis of the waste, groundwater, surface water, and the surrounding soils at the 12 sites for the purpose of physical and chemical characterization.

4. Engineering/economic and environmental assessment of the waste disposal operations at the 12 sites, together with the development of adequate cost data describing a generic variety of waste disposal methods.

The results of each of these activities will be subject to a fully integrated environmental assessment as well as an engineering and economic analysis leading to recommendations. It is anticipated that the results of this study will provide guidance to state and local permitting offices concerning sound disposal practices for coal ash and FGD wastes.

This report focuses on the first activity, namely, identification of candidate sites from which sites will be chosen for detailed characterization and environmental monitoring. To place the candidate site selection in perspective, in 1980 there were more than 1000 fossil fuel-fired steam-electric plants in operation in the United States, with a total generating capacity exceeding 400,000 megawatts. Well over half of this capacity is capable of coal firing. Most of the coal-fired plants are located in the eastern portion of the United States, although the number of plants and generating capacity are growing in the west.

All coal-fired utility boilers are equipped with high-efficiency particulate control systems so that there are a wide variety of coal ash disposal sites potentially available for study. Considerably fewer plants have operational FGD systems, although most of the newer plants (started up since 1974) use this system. With the promulgation of revised New Source Performance Standards (NSPS) and additional restrictions regarding Prevention of Significant Deterioration (PSD) and nonattainment areas, it is anticipated that the use of FGD systems will increase and at some future time will be required for all new coal-fired utility boilers. In 1980, there were 55 utility plants with full-scale FGD units in operation and about a dozen or more plants that are equipped with particulate scrubbing systems that also remove SO_2.

The overall approach to choosing utility disposal sites for detailed characterization and environmental monitoring involves two steps:

- The first step was a preliminary evaluation of all coal-fired plants in the country on which data are available in order to select about 18 candidate sites and a number of back-up sites.

- In the second step, these candidate sites were subjected to close evaluation on the basis of which 6 sites will be selected for detailed analysis.

This Site Selection Report describes:

- The available data and information base on coal-fired utility power plants.

- The methodology and approach used to identify candidate sites. Engineering, hydrogeologic, and other considerations were employed in the selection process.

- The recommended candidate and back-up sites along with some other sites of potential future interest.

- The final selection process leading up to 6 sites being evaluated in detail.

2.0 METHODOLOGY AND APPROACH

2.1 AVAILABLE DATA BASE

The data base employed for the site selection process included the following:

- Data provided by VERSAR, Inc. To provide background information for this project, VERSAR, Inc. completed a study for the EPA (under Contract No. 68-02-2618) on the selection of representative coal ash and FGC waste disposal sites.(1) The draft report, data August 1979, provides baseline data. VERSAR used a literature search, data provided by utilities, and site visits to categorize utility waste disposal practices and develop selection criteria. In addition to the draft report, the Arthur D. Little team had access to the detailed data sheets from about 160 U.S. power plants that replied to the VERSAR questionnaire.

- Data from Radian Corporation and Section 308 letter responses on a large number of coal-fired power plants. Radian, under a Basic Order Agreement, worked with EPA/Effluent Guidelines Division (EGD) on a variety of issues. Using earlier work done for EGD by Hittman Associates, Radian developed baseline data on ash handling and water management at a large number of power plants. Hittman analyzed data obtained by the EPA through a number of industry questionnaires (308 letters). The 308 letter responses were made available to the Arthur D. Little team as background information.

- A Radian Corporation study for EPA/Office of Solid Waste entitled "Study of Non-Hazardous Waste from Coal-Fired Electric Utilities." (2) A preliminary draft report was published in late 1978.

- Data from the Federal Energy Regulatory Commission on steam-electric power plants in the United States.

- The Arthur D. Little team's own background knowledge of water and waste management at power plants. This knowledge had been gained through Arthur D. Little's work for EPA under contracts 68-02-2654 and 68-03-2334 and other activities concerning disposal of flue gas cleaning (FGC) waste from utilities and industrial boilers.

- Open literature, in particular, the Flue Gas Desulfurization Information System (FGDIS) maintained for the EPA, under contract by PEDCo(7).

In addition, efforts were made by the investigators to secure additional data and solicit information on the perceptions and views of the utility industry. With the guidance of EPA, the following specific steps were taken:

- Two Committees were set up: The Advisory Committee and the Technology Committee. Members of these committees included representatives of industry, such as Edison Electric Institute (EEI), American Public Power Association (APPA), and a number of utilities. Membership of these committees is listed in Exhibit B. Members of these committees participated in a review of the Work Plan for this project and the initial efforts in the site selection process. Their comments on the work done to date were reviewed at a meeting on March 11, 1980. Comments were also subsequently forwarded in writing by Edison Electric Institute. These comments were taken into account in the preparation of this report.

- Through the help of some of the utilities and some of the committee members, the investigators also contacted a number of utilities from whom information was not received during the VERSAR study.(1) By the end of January, 1980, approximately 100 new questionnaires along with cover letters were sent out to these utilities. Following this mailing, numerous telephone calls were made to many of these utilities so as to insure the questionnaires were received. Any responses received from these utilities through May 19, 1980, were incorporated into the site selection process. This date was established as a cut-off point by EPA, based on recommendations from the contractor. As of that date only 11 responses had been received.

- Contacts with individual utilities continued throughout the site selection process, particularly in the gathering of the additional information that resulted in the final selections.

Considering the strenuous efforts made by both VERSAR and the contractor on the project to collect data, it is believed that all the information that could reasonably be expected has been incorporated into the site selection process.

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

2.2 OVERALL APPROACH

2.2.1 Priorities for Site Selection Consideration

The overall purpose of this project is to obtain data and information concerning the storage, treatment, and disposal of coal ash (fly ash and bottom ash) and FGD wastes from coal-fired steam-electric generators. The project involved environmental monitoring, data gathering, and economic assessment of disposal practices at six (6) sites at various locations around the country. Results of the study will provide the technical background data and information needed to assist the EPA in determining the extent, if any, to which disposal of these wastes needs to be managed in order to protect human health and the environment.

The disposal methods examined in the project included the most prevalent methods used in the industry as well as those which are likely to represent the best control technology practices for disposal of coal ash alone, coal ash/FGD waste combined, and, if appropriate, FGD waste alone. Each specific disposal operation was evaluated for its current and potential impact on ground/surface water quality and other environmental impacts in the vicinity of the disposal site.

This project is undertaken to support the EPA in their regulatory responsibility under RCRA concerning utility solid waste disposal. Site selection criteria have been prioritized to reflect their relative importance to this particular effort. Specifically, highest screening priority is given to three subject areas that are both characteristically important for utility solid waste disposal and principal regulatory responsibilities under RCRA, rather than other laws. Using this philosophy, the three high-priority subject areas are:

- impacts on groundwater quality;
- impacts on surface water quality from non-point sources; and
- use of potentially mitigative design, management, or control practices.

Table 2.2.1 lists the categories of considerations under RCRA. In almost all cases, the issues in the last five categories are either deferred or are considered to be of marginal importance to utility solid waste disposal. They will still be considered in the environmental assessment work, if applicable; however, there are few, if any, reasons to favor a site on the basis of study opportunities in the lower-priority subject areas listed in the table.

to utility
solid
waste
disposal

For Page Numbering

Table 2.2.1

CONSIDERATIONS UNDER RCRA

I. HIGHEST PRIORITY CONSIDERATIONS

- Groundwater
- Non-point Source Surface Water
- Control Practices

II. LOWER PRIORITY CONSIDERATIONS

- Land Use Issues
- Biological Issues
- Air Quality Issues
- Point-source (NPDES) Water Discharge Issues
- Impacts of Chemical or Physical Waste Treatment Facilities
- Impacts of Waste Storage
- Unusual Security, Contingency, Recordkeeping, or Training Issues

2.2.2 Approach

2.2.2.1 Basis

The environmental impact (and hence potential threat to human health and the environment, if any) of FGC waste disposal is influenced by three factors:

- types of wastes generated,
- disposal methods used, and
- waste disposal site characteristics (e.g., geology, hydrology, climate).

Therefore, during the site selection process, it has been necessary to identify a mix of waste types, modes of disposal, and site characteristics so as to bracket the various levels of environmental impact that can occur.

In the selection of a mix of candidate sites, the overall approach has been to focus on sites that will permit reasonable data gathering and assessment. Although the overall purpose of this study is to develop reasonable guidelines for all kinds of disposal sites, including the very complex ones, it has been necessary for this study to select sites where the data gathered during the one-year monitoring period can be assessed with a reasonable level of confidence. To do otherwise would lead to obtaining data from sites where reasonable data interpretation is not possible and thus waste the available time and fundings. For this reason very complex sites where reasonable data interpretation is not possible have been excluded from consideration as potential sites. Complexity could result from a number of factors such as complex hydrogeology on a site, the existence of external influences on groundwater, or very complex disposal practices.

The overall approach in choosing disposal sites for detailed characterization and environmental evaluation involved two steps:

1) The first step was a preliminary evaluation of available data on all coal-fired power plants in the United States in order to select 18 candidate sites and 8 backup sites.

2) In the second step, the candidate sites were subjected to closer evaluation, including site visits, preliminary testing of grab samples of wastes, and detailed geotechnical and hydrogeologic evaluation. In addition the willingness of the utility concerned to cooperate in this study was an important factor. On the basis of these evaluations, the final six sites were selected.

6

2.2.2.2 Candidates for the Selection Process

The selection of the candidate and backup sites was based on the premise that environmental impacts of FGC waste disposal--hence, any potential threat to human health and the environment--are primarily influenced by three factors:

1) Type of waste to be disposed
2) Disposal method to be employed
3) Disposal site characteristics (soil type, hydrogeology, climate, etc.).

The selection of the candidate and backup sites primarily focused on ensuring, as far as practicable, that the entire mix of waste types generated, disposal methods employed, and site characteristics existing at utility waste disposal sites would be adequately represented by the final sites selected for evaluation. In addition, the approach focused on sites where cost-effective data gathering and reliable assessment of data were possible.

To achieve the overall objective of this project, technical information was needed which would apply to all kinds of disposal sites, including very complex ones. However, to maintain a reasonable budget and schedule for the project, it was necessary to select sites where data from 1 year of monitoring could be used for reliable assessment. Therefore, very complex sites where reliable data interpretation is not possible (on technological or hydrogeologic grounds) were eliminated from further consideration. Nevertheless, the overall plan for characterization and environmental evaluation of the final sites was designed to permit assessment and development of recommendations applicable to complex sites, complex waste types, and complex methods of disposal.

The first step in selecting the candidate and backup sites involved dividing the contiguous 48 states into 14 "discussion regions," each of which corresponded to 1 or more physiographic regions. This division had the following advantages: (1) it produced 14 somewhat distinct groups, each containing a manageable number of plants for detailed and iterative evaluation; (2) it allowed the investigators to determine whether or not the disposal operations at a plant were generally typical of practices throughout a region and a particular disposal practice was likely to be continued or more extensively used; and (3) it allowed the investigators to determine whether or not the hydrogeologic and environmental conditions at a site were representative of others in the region. As the evaluation got underway, sites which appeared promising were compared with potential candidate sites in adjacent regions so that the most promising sites could be selected. Nevertheless, a strong attempt was made to choose desirable sites in as many regions as possible, so that sites representing the range of both present and anticipated future utility FGC waste disposal practices would be included.

The final steps in selecting the candidate and backup sites comprised an iterative process, taking into account the three aforementioned primary factors which influence environmental impacts of FGC waste disposal:

1) Waste Type: Available information indicated that six categories of wastes constitute the vast majority--fly ash, bottom ash, combined fly and bottom ash, FGD waste, combined FGD waste and fly ash, and stabilized FGD waste disposal. These categories are likely to remain the major future options of importance.

2) Method of Disposal: Ponding and landfill type operations are practicable for many wastes. FGD wastes, when disposed of alone, are usually disposed of by ponding only. In the future, with forced oxidation methods, FGD waste disposal by itself in the form of gypsum stacks may be practical. Stabilized disposal of FGD waste as moist soil-like material in landfills is likely to be very important. Mine disposal is a special subcategory of landfill type disposal and was also considered.

3) General Location: While the initial screening was done on the basis of 14 discussion regions, the final ranking (for presentation) was based on dividing the United States into 3 environmental zones: Coastal, Interior, and Western. Sites near the Atlantic and Gulf Coasts were grouped as Coastal. Sites in or west of Montana, Wyoming, Colorado, and New Mexico were considered Western. The remainder of the sites were considered Interior.

The sites with a particular mix of waste type, method of disposal, and general location were then grouped together. The sites within each group were ranked relative to each other, and the more promising ones became the candidate and backup sites.

The initial list of 26 candidate and backup sites provided a broad mix of options to be subjected to further analysis leading to the selection of the final sites.

2.2.2.3 Final Selection Process

The list of candidate and backup sites were then subject to a detailed evaluation as follows:

i) Initial contact with the utility involved to obtain additional information and also obtain a first reading on their willingness to cooperate in this study if their site after detailed evaluation appeared suitable.

ii) A visit to the site by a two or three person team including engineers and hydrogeologists. In addition to firsthand evaluation of the power plant and disposal site, this team also studied the available data available in state, local and federal offices in the area about the hydrogeological and environmental setting of the area and the site. This led to a detailed report to the EPA Project Officer on the suitability of the site.

iii) If the site with the approval of the EPA appeared suitable, additional interaction was initiated with the utility to ascertain their willingness and ability to cooperate.

iv) Provided the utility was willing to cooperate, a detailed Test Plan was prepared for review first by the EPA and then by the utility. Taking into account all comments, the Test Plan formed the basis for more at each of the six (6) sites.

2.3 REGIONAL DIVISION OF THE UNITED STATES

In order to facilitate the site selection process, the United States has been divided geographically into 14 regions, as shown in Figure 2.2. This division resulted in a manageable number of plants for detailed and iterative evaluation by the investigators involved in the site selection process. More importantly, however, each discussion region corresponds to one or more physiographic region.

Physiographic regions have been defined by a number of authors, including Hunt,(3) Fenneman,(4)(5) and Thornbury.(6) Standard reference works, such as the work of the three authors mentioned, were consulted to define the physiographic provinces of the United States. For this project, these provinces were grouped into 14 major divisions. Each physiographic province has characteristics peculiar to itself in that a distinctive geological framework is present which gives rise to distinctive landforms. The landforms express the influences of the structural geologic parent materials, weathering effects, erosion and sedimentation, and climatic factors. In general, each physiographic province has a distinctive climate, particular vegetative types, characteristic soils, a particular water regime, and differences in principal natural resources. These physiographic provinces thus form a good basis for the division of the United States for use in this study.

Division of the country into these regions allowed the investigators to determine whether or not the disposal operations at a plant were typical of practices which were general throughout a region and the likelihood of continued or more extensive use of a particular disposal practice. It also allowed the investigators to detemine whether the hydrogeologic and environmental conditions at a site were representative of others in the region. (Assuming these conditions were representative, they also were examined to determine that a reasonable assessment of the site could be made in one year of monitoring.) The sites which appeared promising were compared with potential candidate sites in adjacent regions so that more promising alternative sites could be selected. Details on the division into 14 regions and a brief account of the conditions in each region are presented in Exhibit C.

Climatic factors (temperature, gross and net precipitation, and frost penetration) are generally similar throughout a given physiographic region, although some regions display significant differences in climatic factors when the geologic framework has been a predominant influence on the formation of the present day landforms.

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

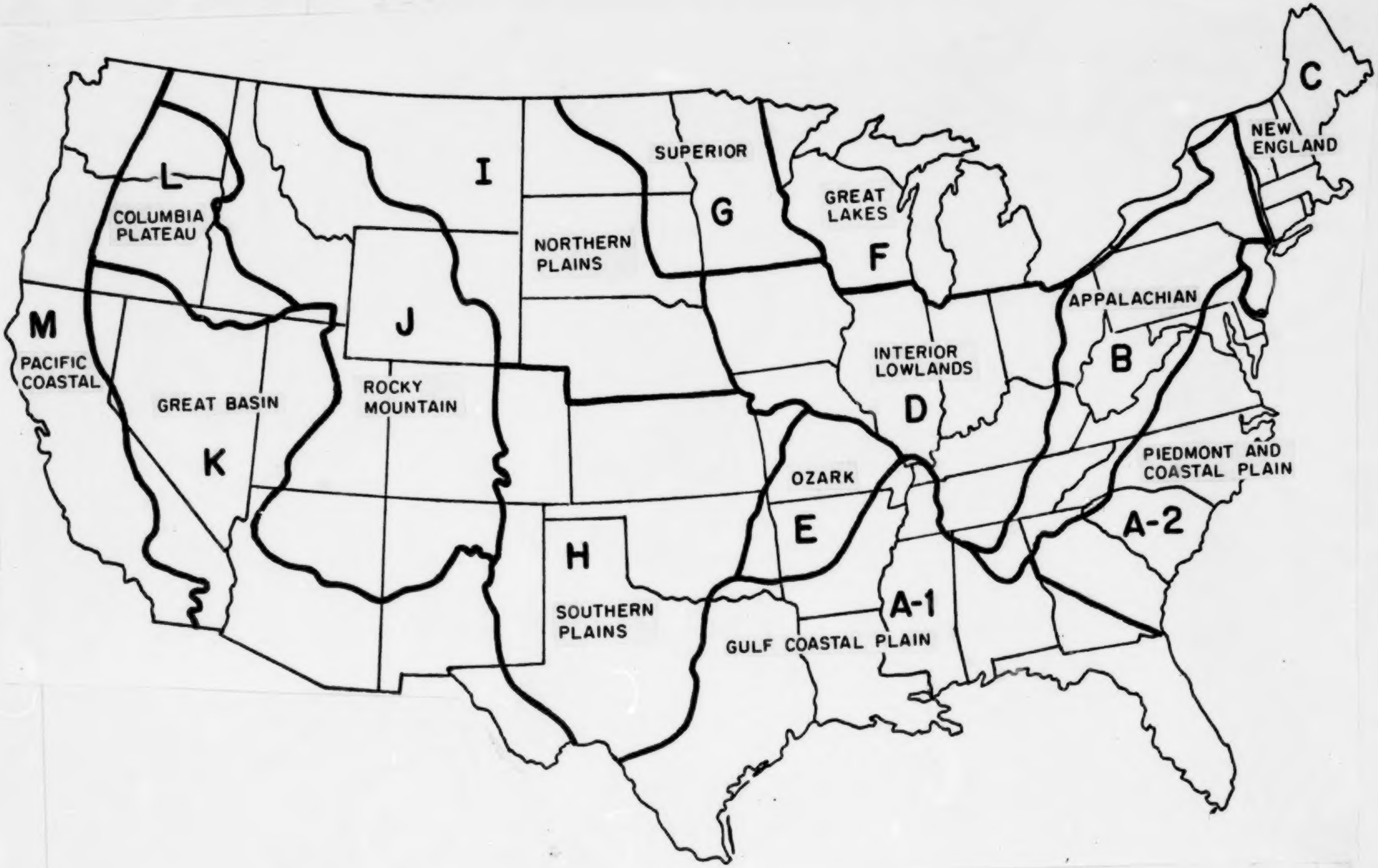

C
NEW ENGLAND
SUPERIOR
I
L
COLUMBIA PLATEAU
G
GREAT LAKES
NORTHERN PLAINS
F
APPALACHIAN
M
J
PACIFIC COASTAL
B
INTERIOR LOWLANDS
GREAT BASIN
ROCKY MOUNTAIN
D
K
PIEDMONT AND COASTAL PLAIN
OZARK
E
A-2
H
SOUTHERN PLAINS
A-1
GULF COASTAL PLAIN

FIGURE 2.2 SITE SELECTION PROCESS REGIONS

10 Lines to End of Typing Area

For Page Numbering

ADL-054 1270 300M

USE THIS SHEET FOR REPORT TYPING 8 1/2 x 11

TOP

The approach described above was used, with emphasis on the expertise of the group of investigators, to develop the overall list of candidate and back-up sites recommended in this report.

The candidate site selection process, as described in this report, was based on available information. It should be noted that further evaluations including detailed site visits are expected to turn up additional information concerning influences on the disposal site, engineering/economic considerations, and issues such as utility cooperation. This information may alter the ranking of a recommended candidate site. It is precisely for this reason that back-up sites have been recommended.

10 Lines
to End of
Typing Area

For Page Numbering

ADL 064 1279 200M

2.4 FGC WASTES & DISPOSAL OPERATIONS

2.4.1 FGC Waste Types

2.4.1.1 Coal Ash

Coal-fired utility boilers generate two types of coal ash - fly ash and bottom ash. (Usually mill rejects and economizer ash are lumped into one of these two major categories.) Both constitute the non-combustible (mineral) fraction of the coal and the unburned residuals. Fly ash, which accounts for the majority of the ash generated, is the fine ash fraction carried out of the boiler in the flue gas. Bottom ash represents that material which drops to the bottom of the boiler and is collected either as boiler slag or dry bottom ash, depending on the type of boiler.

The total amount of coal ash produced is directly a function of the ash content of the coal fired. Thus, the total quantity of ash produced can range from a small percentage of the weight of the coal fired to as much as 35%. The partitioning of ash between fly ash and bottom ash usually depends on the type of boiler. Standard pulverized coal-fired boilers typically produce 80-90% of the ash as fly ash. In cyclone-fired boilers the fly ash fraction is usually less; in some cases, the bottom ash constitutes the majority of ash collected.

Fly ash carried in the flue gas stream can be collected in a number of ways to meet current particulate emission control limitations. Typical methods include mechanical collection, electrostatic precipitation, fabric filtration, and wet scrubbing. Mechanical collectors generally are not capable of meeting present emission control limitations and, when used, are generally followed by either an electrostatic precipitator or a high-efficiency wet scrubbing system.

2.4.1.2 FGD Sludges

FGD systems can be generally categorized in two groups: nonregenerable, or throwaway, systems which produce a waste material for disposal; and regenerable, or recovery, systems which produce a saleable by-product (sulfur or sulfuric acid). As of late 1982, over 100,000 Mw of equivalent scrubbed capacity at 127 coal-fired electric utility plants in the United States are committed to the application of FGD systems (including systems in operation, under construction, or planned).(7) About 95% of this capacity involves nonregenerable system, most of which employed lime or limestone to produce a solid waste, calcium-sulfur salt, for disposal. This technology can be expected to dominate in boiler applications of FGD systems for the foreseeable future.

Most commercial nonregenerable processes today involve wet scrubbing where gases are contacted at some stage with aqueous slurries or solutions of absorbent. Most nonregenerable systems can withstand relatively high levels of particulate and trace contaminants and many in the past have been designed for simultaneous SO_2 and particulate removal. However, to ensure more reliable service, most systems being installed today on utility-scale boilers, follow high-efficiency electrostatic precipitators. Notable exceptions to this are some of the systems which utilize the alkalinity in the fly ash for SO_2 control.

The principal types of nonregenerable systems producing solid wastes for disposal are:

- conventional direct lime scrubbing,
- conventional direct limestone scrubbing,
- limestone scrubbing with forced oxidation,
- alkaline fly ash scrubbing, and
- dual alkali scrubbing.

Two systems produce a soluble waste which may be discharged as an aqueous liquor to holding ponds:

- once-through sodium scrubbing and
- ammonia water scrubbing (not employed in utility boilers at present).

Table 2.4.1 presents data on FGD systems in operation as of late 1982. As shown in the table, essentially all utility applications of nonrecovery technology involve solid waste-producing systems.

Dry nonrecovery processes have recently been commercially demonstrated in the United States: a 110 Mw lime-based unit at Northern States Power's Riverside Station and a 440 Mw sodium carbonate-based system at Montana-North Dakota Utilities' Coyote Station. In addition, twelve more systems for full-scale utility applications are in the early stages of planning or design. All dry scrubbing systems involve simultaneous particulate and SO_2 control, and all offer the advantage of not requiring flue gas reheat, which wet processes generally do require. It is important to note, however, that there were no dry nonrecovery processes in commercial operation on utility boilers during the time the site selection process was taking place.

As in the case of nonrecovery processes, recovery processes can also be categorized into wet and dry types according to the mode of SO_2 removal. They can be further classified according to the type of byproduct produced, concentrated SO_2 for conversion to sulfur or sulfuric acid, sulfur only, or acid only.

Table 2.4.1

SUMMARY OF FGD SYSTEMS EXPECTED TO BE IN COMMERCIAL OPERATION ON UTILITY BOILERS IN LATE 1982

	OPERATIONAL	
RECOVERY PROCESSES	Number of Units	MW[a]
• Aqueous Sodium Carbonate/ Spray Drying	1	100
• Citrate	1	60
• Lime	0	
• Limestone	0	
• Lime/Limestone	0	
• Magnesium Oxide	1	240
• Wellman Lord	7	1959
Subtotal - Recovery Processes	10	2359
NON-RECOVERY PROCESSES		
• Dual Alkali	3	1181
• Lime	23	9680
• Limestone	38	13920
• Limestone/Alkaline Fly Ash	2	1500
• Lime/Alkaline Fly Ash	9	2838
• Lime/Limestone	2	20
• Lime/Sodium Carbonate	1	100
• Lime/Spray Drying	1	110
• Sodium Carbonate (Once-Through Sodium)	5	1255
• Sodium Carbonate/Spray Drying	1	440
Subtotal - Non-Recovery Processes	86	31044
TOTAL	96	33403

---

[a] Capacities given are Equivalent Scrubbed Capacities

Source: Compiled by Arthur D. Little, Inc. based on Reference 7.

At present, only four process technologies have been commercially demonstrated on large industrial or utility-scale boilers, the Wellman-Lord, magnesium oxide scrubbing, citrate scrubbing and the aqueous sodium carbonate/spray drying systems. Of these four process technologies, three are wet scrubbing processes while one, the aqueous sodium carbonate system, is a dry process.

Other important points to be noted include the following:

- The vast majority of utility FGD systems with at least one and one-half years of operation, as of mid-1979, (required as a minimum if a disposal site was to be selected for this program) were based on lime or limestone scrubbing processes.
- Recovery FGD systems produce relatively small amounts of waste compared to nonrecovery FGD systems and comprise a minor portion of total FGD system installations or applications.
- Dry FGD scrubbing systems were not in commercial operation at the time of the site selection process.

For purposes of this project, fly ash, bottom ash, and wastes from nonrecoverable solid waste-producing FGD processes have been designated the utility wastes to be considered. For a broad review of FGC waste characterization and waste disposal, the reader is referred to References 8 and 9.

2.4.2 Disposal Methods

A number of methods are potentially available for the disposal of coal ash and FGD wastes on land and in the ocean. Table 2.4.2 lists the disposal options potentially applicable, broadly categorized according to the nature of the wastes and the type of disposal. At present, all coal ash and FGD wastes are disposed on land. Utilization is growing but is still likely to grow less than total generation of FGC wastes in future years. For an overview of ash utilization, the reader is referred to Reference 10.

To provide some perspective on current utility disposal practices, Table 2.4.3 shows a preliminary matrix summarizing currently available information on the disposal of coal ash and FGD wastes at utility power plants over 200 Mw in capacity with more than 80% of their power generation from coal. Tables presented later in Section 3.0 give the analogous categorization matrices for each of the 14 regions.

Table 2.4.2

POTENTIAL DISPOSAL OPTIONS

	Ash	FGD	Co-Disposal
Land			
Wet Impoundments - Conventional	C	C	C
Gypsum Stacking	-	P	P
Managed Fill	C	C	C
Surface Mine	C	P	C
Underground Mine	C	P	P
Ocean Disposal			
Shallow	P	P	P
Deep	P	P	P

C = Commercial Practice
P = Reasonable Potential

Basis: Only ash and nonrecovery FGD processes included.

Source: Arthur D. Little, Inc.

Table 2.4.3

MATRIX OF FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS

≥ 200 Mw IN THE UNITED STATES[a]

Type of Waste	Number of Plants		
	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	18	46	6
Bottom ash only	29	13	29
Combined fly and bottom ash	69	9	16
FGD waste only	5	-	-
Mixed fly ash and FGD waste	7	7	-
Mixed bottom ash and FGD waste	1	-	1
Mixed fly ash and FGD waste (stabilized)	2	6	-
Mixed fly ash, bottom ash, and FGD waste	2	1	1

---

[a] Coal-fired plants (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal.

Source: Compiled by Arthur D. Little, Inc. based on Utility Plant Data Survey Sheets used in developing Reference 1.

Some general conclusions are evident from an examination of Table 2.4.3.

- Combined fly and bottom ash ponding is the most common method of disposal for coal ash.
- Landfilling of fly ash is a significant disposal option.
- Interim ponding followed by landfilling seems to be a major method of disposal of bottom ash where separate disposal of bottom ash is practiced. Bottom ash is also often ponded.
- Separate ponding of fly ash and bottom ash is practiced to a lesser extent than combined fly ash and bottom ash ponding.
- Mixed disposal of ash and FGD waste and disposal of stabilized FGD waste are only now coming into more extensive use.

Co-disposal and stabilization processes for FGD wastes (which usually involve fly ash and lime) are coming into prominence at present. However, at the time of the site selection process there were few sites available that had such practice for one and one-half years or more.

To consider current disposal from another perspective, Table 2.4.4 presents the data on ash handling systems used by utility plants on the basis of physiographic region. It is clear that in the regions with the highest concentration of coal-fired utility plants (B and D) wet handling of fly and bottom ash is the most common procedure.

To summarize, the majority of coal ash and FGD wastes are presently disposed by ponding. In the future, economic, environmental, and regulatory developments are likely to encourage the use of dry disposal methods. Complementing the development of dry disposal methods, FGD waste stabilization processes are likely to find a broader acceptance. As of mid-1980, there were more than 12 plants practicing FGD waste stabilization;(11) in the future this number is likely to grow.

2.4.3 Trends in FGC Waste Generation and Disposal

As coal utilization in utilities and large industrial boilers increases, the quantity of FGC wastes, particularly those associated with flue gas desulfurization, will increase dramatically. The preponderant part of these FGC wastes will require disposal. Over the long term, utilization is expected to grow but at a slower rate than that of FGC waste generation To date, there is some utilization of coal ash but no utilization of FGD wastes in the United States. Table 2.4.5 shows projections of coal ash and FGD wastes from utility boilers (excludes industrial boilers) through the year 1995. A indicated in this table, the quantity of coal ash and FGD waste generated in 1995 is estimated to be more than twice that generated in 1980.

TABLE 2.4.4

DIVISION OF UTILITY PLANTS BY ASH HANDLING SYSTEMS AND PHYSIOGRAPHIC REGION

Physiographic Region	Dry Fly + Dry Bottom	Dry Fly + Wet Bottom	Dry/Wet Fly + Wet Bottom	Wet Fly + Dry Bottom	Wet Fly + Wet Bottom
A1 - Gulf Coastal Plain	1	5	0	0	9
A2 - Piedmont & Coastal Plain	1	2	1	0	17
B - Appalachian	0	12	1	0	30
C - New England	0	1	0	0	1
D - Interior Lowlands	0	6	6	1	22
E - Ozark	0	1	0	0	2
F - Great Lakes	0	8	3	0	6
G - Superior	3	1	1	0	2
H	0	1	0	0	0
I	0	1	3	0	2
J } Great Plains & West	1 } 4	3 } 5	0 } 3	0 } 0	2 } 5
K	2	0	0	0	1
L	0	0	0	0	0
M	1	0	0	0	0
TOTAL NUMBER OF PLANTS (% of Total)	9 (5.6)	41 (25.6)	15 (9.4)	1 (.6)	94 (58.8)

Source: Compiled by Arthur D. Little, Inc. based on Utility Plant Data Survey Sheets used in Developing Reference 1.

Table 2.4.5

PROJECTED GENERATION OF COAL ASH AND FGD WASTES FROM UTILITY BOILERS

(000 Metric Tons)

		PROJECTED	
	1975	1985	2000
Coal Ash	-	64,440	84,800
FGD Wastes	-	21,050	29,860

NOTE: Excludes Industrial Boilers

Source: Reference 12.

At present, wet ponding disposal in managed landfills and mine disposal are employed for utility wastes. Ponding can be employed for a variety of FGC wastes including unstabilized FGD wastes. However, the construction of dikes or other means of containment for ponds is generally expensive. Thus, in the future, particularly if dry handling of ash and stabilization of FGD wastes is more widely practiced, ponding will probably be limited to those disposal sites that can be converted to a pond with minimal construction of dikes. A special case of wet ponding, however, currently under evaluation involves the stacking of sulfate rich (gypsum) FGD wastes. If the operation were analogous to that for phos-gypsum, gypsum slurry (typically from forced oxidation systems) would be piped to a pond and allowed to settle; the supernate would be recycled. Periodically, gypsum would be dredged and stacked around the embankments, thereby actually becoming part of the contaminated dikes. Similarly, managed landfills can also be employed in the disposal of both fly and bottom ash and FGD wastes. In contrast to ponding operations, however, FGD waste and/or coal ash handled wet is generally thickened and dewatered to increase the solids content prior to disposal in a managed landfill. In the future, to eliminate necessary dewatering operations, etc., utilities may tend towards dry fly ash handling, whereby the fly ash can be directly landfilled with no treatment. Landfilling of FGD wastes, however, would always require some form of dewatering followed by codisposal with ash or stabilization prior to landfilling. Mine disposal of coal ash and FGD waste is not widely used currently, but it is receiving increased attention. Presently, it appears that coal mines, in particular surface mines are the most likely mine candidates for utility waste disposal. Additionally, a future option for the disposal of FGC wastes may be the ocean. Ocean disposal of FGC wastes is not practiced today, however, if practiced under environmentally acceptable conditions, it could represent an important disposal option, particularly for coastal plants and plants situated in the Northeast where land availability for waste disposal is limited.

In addition to the issues previously discussed, the factors listed below will significantly influence both the future generation of FGC wastes and the methods by which they are disposed.

- An increase in coal-fired capacity in the United States. In 1979, the total U.S. coal-fired electric utility generating capacity was estimated at over 235,000 Mw in 395 plants.(13) The estimated capacity is expected to increase 1990 to over 343,000 Mw.(14) Use of coal in large industrial boilers (+25 Mw equivalent or larger) is likely to further increase the total coal-fired capacity.(15)

- A major increase in the application of scrubber technology by utility boilers and a consequent increase in FGD waste generation. At present over 33,000 Mw of equivalent scrubbed capacity at 56 plants (96 units) utilize FGD systems. As of late 1982, over 100,000 Mw of equivalent scrubbed capacity has been committed to FGD systems.(7) Future increases are likely to be even more dramatic.

- Advances in stabilization technology for FGD wastes which permit landfill disposal of partially dewatered solids instead of ponding of sludges that are difficult to handle. In the future, disposal of wastes in managed fills is likely to grow. In many cases, this may require co-disposal or stabilization prior to disposal.

- Environmental regulatory developments including the Clean Air Act of 1977 and the Resource Conservation and Recovery Act of 1976 (RCRA).

New Source Performance Standards (NSPS) for major air emissions were issued in June, 1979(8); and represent a driving force in the selection of utility air pollution control systems and the generation of resultant ash and flue gas cleaning wastes. Under RCRA, the Agency has indicated the likelihood that utility coal ash and FGD wastes will continue to be regulated as non-hazardous at the initiative of the individual states, with the EPA prospectively offering general guidance documents to the states as the result of this and related studies.

- Energy-related regulatory developments under the Energy Supply and Environmental Coordination Act (ESECA) of 1974, the Power Plant and Industrial Fuel Use Act (FUA) of 1978 and the Omnibus Reconcilliation Act (OBRA) of 1981. The Department of Energy (DOE) was empowered to issue prohibition orders to major steam electric generating utilities to convert to coal from other fossil fuels (e.g., oil and gas) under ESECA and FUA. OBRA, part of the 1981 budget resolution, amended FUA and provided for utility coal conversions to be undertaken on a voluntary basis only. Utilities could elect to keep their prohibition orders under ESECA or FUA, request new conversion orders under OBRA or continue operations as they had in the past. The major reasons for coal conversions include the fact that the use of domestic coal versus imported oil is looked upon favorably by regulatory and oversight agencies. Conversion may also be favored on economic grounds (i.e., in a time of limited new plant construction because of low demand increases, investment capital is channelled to conversions since the rate of return for utilities is based on capital investment). Additionally, from an environmental regulatory standpoint, the converted plant is not classified as a new source, therefore, emissions standards are not as stringent as for new facilities. It is reported that about 40 units (nearly 8500 Mw) were in the process of being converted in late 1982. It is also of interest to note that 35 additional units (about 7500 Mw) are anticipated to undertake coal conversion.(19)

To provide some perspective on projections, the following tables are presented:

- Table 2.4.6 presented projections of new coal-fired utility plants during the period 1982-1990 by region. Nearly 30% of the estimated new capacity is expected to be in the Great Plains and the West.

- Table 2.4.7 and Table 2.4.8 present projections of new FGD systems by region during 1982-1990.

Table 2.4.6

PROJECTION OF NEW COAL-FIRED UTILITY PLANTS[a] IN THE UNITED STATES BY PHYSIOGRAPHIC REGION FOR THE PERIOD 1982-1990

Physiographic Region		Number of New Plants[a]		% of Total		Nameplate Generating Capacity (Mw)		Percent of Total	
A1 - Gulf Coastal Plain		27		22.1		21,615		25.9	
A2 - Piedmont & Coastal Plain		7		5.7		6,472		7.8	
B - Appalachian		3		2.5		2,588		3.1	
C - New England		2		1.6		1,268		1.5	
D - Interior Lowlands		26		21.3		17,583		21.1	
E - Ozark		4		3.3		3,437		4.1	
F - Great Lakes		9		7.4		3,861		4.6	
G - Superior		3		2.5		985		1.2	
H		16		13.1		7,505		9.0	
I		6		4.9		4,180		5.0	
J	Great Plains & West	10	41	8.2	33.6	5,172	25,652	6.2	30.7
K		8		6.6		7,795		9.3	
L		1		0.8		1,000		1.2	
M		0		0.0		0		0.0	
TOTAL:		122		100.0		83,461		100.0	

---

[a] Includes both new units at existing plants and new plants.

Source: Compiled by Arthur D. Little, Inc. based on References 13 and 14.

Table 2.4.7

PROJECTION OF NEW FGD SYSTEMS IN THE UNITED STATES BY PHYSIOGRAPHIC REGION FOR THE PERIOD 1982-1990

FGD Equivalent Scrubbed Capacity (Mw)[a]

Physiographic Region		Under Construction		Contract Awarded or Planned		Total Capacity		Percent of Total	
A1 - Gulf Coastal Plain		2,079		21,428		23,507		33.6	
A2 - Piedmont & Coastal Plain		984		1,050		2,034		2.9	
B - Appalachian		925		1,500		2,425		3.5	
C - New England		0		1,630		1,630		2.3	
D - Interior Lowlands		6,142		8,075		14,217		20.3	
E - Ozark		0		1,780		1,780		2.5	
F - Great Lakes		164		0		164		0.2	
G - Superior		0		810		810		1.2	
H	Great Plains & West	1,743	-,448	1,240	14,960	2,983	23,408	4.3	33.5
I		2,900		650		3,550		5.1	
J		3,279		6,170		9,449		13.5	
K		526		3,020		3,546		5.0	
L		0		2,280		2,280		3.3	
M		0		1,600		1,600		2.3	
TOTAL:		18,742		51,233		69,975		100.0	

---

[a] Includes new plants as well as existing plants that will add new units and/or retrofit existing ones.

Source: Compiled by Arthur D. Little, Inc. based on Reference 7.

Table 2.4.8

PROJECTION OF NEW FGD SYSTEMS IN THE UNITED STATES BY PHYSIOGRAPHIC REGION FOR THE PERIOD 1982-1990

Number of New FGD Units[a]

Physiographic Region	Under Construction	Contract Awarded or Planned	Total Units (Plants)	Percent of Total
A1 - Gulf Coastal Plain	4	31	35	28.0
A2 - Piedmont & Coastal Plain	3	2	5	4.0
B - Appalachian	2	3	5	4.0
C - New England	0	3	3	2.4
D - Interior Lowlands	12	14	26	20.8
E - Ozark	0	2	2	1.6
F - Great Lakes	3	0	3	2.4
G - Superior	0	1	1	0.8
H	4	2	6	4.8
I	6	1	7	5.6
J	7	10	17	13.6
K	2	7	9	7.2
L	0	4	4	3.2
M	0	2	2	1.6
Great Plains & West	19	26	45	36.0
TOTAL:	43	82	125	100.0

---

[a] Includes new plants as well as existing plants that will add new units and/or retrofit existing ones.

Source: Compiled by Arthur D. Little, Inc. based on Reference 7.

- Table 2.4.9 presents data on power plants that are currently in the process of converting to coal and those which are believed to be likely candidates for conversion.

As can be seen from these tables, the emerging trend is towards a considerable increase in the generation and disposal of coal ash and FGD wastes. While one can be sensitive to this trend, it was difficult to quantify this in candidate site selection. If one has to select sites with at least one and on-half to two years of operation, it is not always possible to consider changes expected in the future.

However, the investigators took into account the above factors and recommended the following:

- A cognizance of the fact that the growth of new coal-fired power plants and coal utilization in the western part of the United States is likely to be greater proportionately than that in much of the east. It was desirable to choose somewhat more candidate and backup sites in the west than current generating capacity or number of plants would suggest. At least one western site was essential in the final list.

- Because of the increase in disposal in managed fills, it is desirable to choose a greater percentage of such sites than current data would suggest.

The two recommendations listed above are not precise quantitative conclusions; rather the investigators took cognizance of these in recommending candidate sites.

2.5 NUMBER OF CANDIDATE SITES

2.5.1 Basis for Candidate Sites

Under this project the contractor with EPA direction will conduct characterization and environmental monitoring of full-scale utility waste disposal sites. The subsequent decisions to finally focus on 6 sites were made on the basis of a rough estimate of the minimum number of sites necessary to cover waste types and disposal practices and a determination of optimum coverage given available funding.

Given that 12 sites were originally to be chosen for monitoring (but later trimmed to 6), the investigators decided that the preliminary evaluations should result in the recommendation of 18 candidate sites and a smaller number of back-up sites. The reasons for this decision were as follows:

- While there were data available, the investigators had not visited most of the sites. First-hand evaluations during field visits were expected to reveal previously unknown factors leading to rejection of some of the 18 recommended candidate sites.

Table 2.4.9

UTILITY PLANT CONVERSIONS FROM OIL/GAS TO COAL BY PHYSIOGRAPHIC REGION

Physiographic Region	Units that are Committed to Converting to Coal		Units Potentially Under Consideration[a]	
	No. of Units	Mw	No. of Units	Mw
A1 - Gulf Coastal Plain	6	985	2	872
A2 - Piedmont & Coastal Plain	13	3635	3	606
B - Appalachian	0	0	6	786
C - New England	16	3140	25	4305
D - Interior Lowlands	0	0	2	1040
E - Ozark	0	0	0	0
F - Great Lakes	0	0	0	0
G - Superior	0	0	0	0
H	0	0	0	0
I	0	0	0	0
J	0	0	0	0
K Great Plains & West	6	725	0	0
L	0	0	0	0
M	0	0	0	0
TOTAL NUMBER OF UNITS	41	8485	39	7609

---

[a] DOE considers these as potentially capable of conversion to coal, and likely to convert.

Source: Reference 19.

- Issues relating to utility cooperation and other factors were expected to lead to some sites being less suitable that others for this project.

The overall objective was to allow for a 50% margin for such contingencies and, in addition, to have back-up sites. The overall objective was to have, wherever possible, at least two sites for each target waste type and disposal mode.

2.5.2 Targeted Number of Candidate Sites

At the time of site selection, there were more than 350 steam-electric plants in the United States with coal-firing capability. About 340 of these plants had greater than 25 Mw capacity and utilized coal for more than 80% of their power production.

Tables 2.5.1 and 2.5.2 list the number and capacity of coal-fired power plants in 1977 with greater than 25 Mw of total capacity in each of the 14 physiographic regions. Figure 2.5.1 presents the data on a regional basis. These summary tables point out two important features concerning the makeup of the U.S. utility industry:

- About 55% of both the total electrical generating capacity and the plants were located in the two physiographic regions covering the Appalachian (Region B) and Central Interior Lowlands (Region D) areas of the country.

- While the number of coal-fired plants with generating capacity of less than 200 Mw amounted to almost 35% of the total number of coal-fired plants, the cumulative capacity of these plants was less than 5% of the total coal-fired capacity.

Generally, plants with under 200 Mw of capacity were not considered in the preliminary screening of power plants. This decision was based on a number of considerations.

- Quite a few of these plants are located in urban or semi-urban areas and co-dispose of the FGC wastes with other industrial, municipal, or commercial wastes. Such practices could make monitoring and assessment difficult, if not impossible, and potentially outside the original scope of work.

- More than 50% of the plants are also in the two regions (B and D) where the majority of the larger plants are located. An adequate number of sites are therefore available in these regions without considering the smaller plants.

- Many of these smaller plants tend to buy coal on the spot market or fire a number of different types of coal. This could make an assessment of the waste disposal impacts more difficult.

Table 2.5.1

DIVISION OF UTILITY PLANTS[a] BY NAMEPLATE GENERATING CAPACITY AND PHYSIOGRAPHIC REGION
(Number of Plants)

Plant Nameplate Generating Capacity (Mw)	Physiographic Regions														Total Number of Plants
	A1	A2	B	C	D	E	F	G	H	I	J	K	L	M	
25 - 100	2	2	10	0	18	1	14	8	0	4	1	1	0	0	61
100 - 200	0	3	11	0	17	1[c]	7	2	2	4	2	0	0	0	49
200 - 500	4	14	16	1	23	0	11	4	2[d]	1	5	2	0	0	83
500 - 1,000	5	7	12	1	22	1	8[e]	2	5	6	4	0	0	0	73
1,000 - 1,500	7	3[d]	8	0	14	1	0	1	0	0	0	0	0	1	35
1,500 - 2,000	2	2	13	0	3	0	2	0	1	0	1	1	0	0	25
≥ 2,000	1	2	6	0	4	0	1	0	0	0	2	0	0	0	16
TOTAL NUMBER OF PLANTS	21	33	76	2	101	4	43	17	10	15	15	4	0	1	342
Percent Loss of Plants[b]	9.5	15.2	27.6	0.0	34.6	25.0	48.8	58.8	20.0	53.3	20.0	25.0	0.0	0.0	31.9

---

[a] Coal-fired utility plants in the United States ≥ 25 Mw of which at least 80% of the generating capacity in 1977 was from coal.

[b] Percent of plants below 200 Mw cutoff.

[c] Plant is included as a potential candidate site even though its generating capacity is < 200 Mw because it employs an FGD system.

[d] Some plants are included as potential sites even though they were < 80% coal-fired in 1977 because they employ FGD systems.

[e] Plant is included as a potential candidate site even though it was < 80% coal-fired in 1977 because it shares a land disposal site with the St. Clair and Trenton Channel plants.

Source: Compiled by Arthur D. Little, Inc. based on Reference 20.

Table 2.5.2

DIVISION OF UTILITY PLANTS[a] BY NAMEPLATE GENERATING CAPACITY AND PHYSIOGRAPHIC REGION

(Mw)

	Physiographic Regions														
Plant Generating Capacity (Mw)	A1	A2	B	C	D	E	F	G	H	I	J	K	L	M	Total Generating Capacity (Mw)
25 - 100	130	104	622	0	991	59	651	288	0	142	34	59	0	0	3,080
100 - 200	0	509	1,592	0	2,510	194[c]	1,181	252	271	540	360	0	0	0	7,409
200 - 500	1,365	4,835	5,400	459	7,885	0	3,574	1,688	572	228	1,866	805	0	0	28,677
500 - 1,000	3,606	4,551	8,200	652	15,506	923	5,420[e]	1,112	3,582[d]	3,993	2,924	0	0	0	50,469
1,000 - 1,500	8,722	4,131[d]	9,825	0	16,773	1,241	0	1,440	0	0	0	0	0	1,329	43,461
1,500 - 2,000	3,520	3,559	22,586	0	5,464	0	3,575	0	1,558	0	1,525	1,636	0	0	43,423
≥ 2,000	2,379	4,160	15,357	0	10,080	0	3,279	0	0	0	4,678	0	0	0	39,933
Total Generating Capacity (Mw)	19,722	21,849	63,582	1,111	59,209	2,417	17,680	4,780	5,983	4,903	11,387	2,500	0	1,329	216,452
Percent Loss of Capacity b	0.66	2.8	3.5	0.0	5.9	2.4	10.4	11.3	4.5	13.9	3.5	2.4	0.0	0.0	4.8

---

[a] Coal-fired utility plants in the United States ≥ 25 Mw of which at least 80% of the generating capacity in 1977 was from coal.

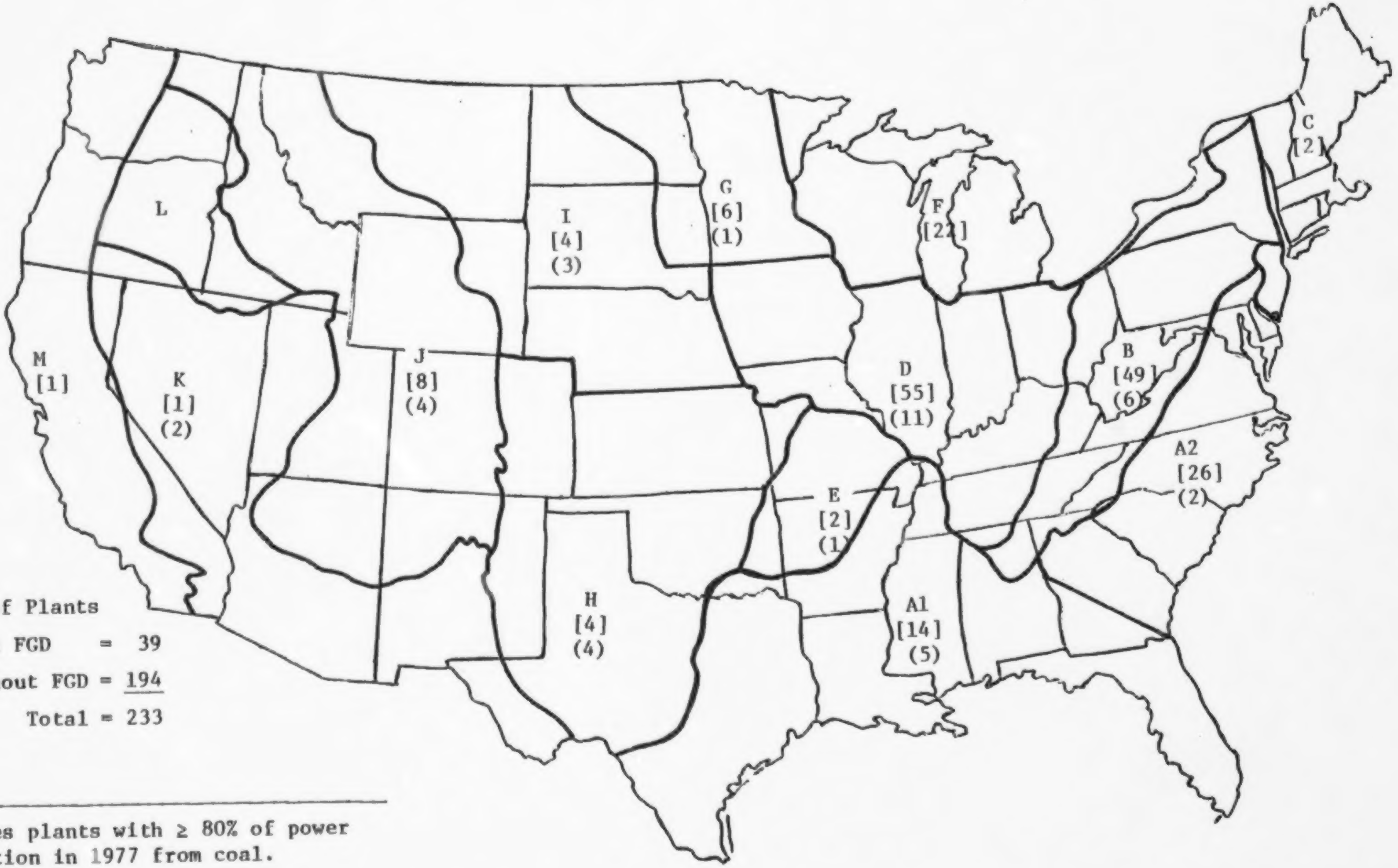
[b] Percent of total generating capacity below 200 Mw cutoff.

[c] Plant is included as a potential candidate site even though its generating capacity is < 200 Mw because it employs an FGD system.

[d] Includes plants as potential candidate sites even though they were < 80% coal-fired in 1977 because they employ FGD systems.

[e] Plant is included as a potential candidate site even though it was < 80% coal-fired in 1977 because it shares a land disposal site with the St. Clair and Trenton Channel plants.

Source: Compiled by Arthur D. Little, Inc. based on Reference 20.


L
M
[1]
K
[1]
(2)
J
[8]
(4)
I
[4]
(3)
G
[6]
(1)
H
[4]
(4)
E
[2]
(1)
F
[22]
D
[55]
(11)
A1
[14]
(5)
B
[49]
(6)
A2
[26]
(2)
C
[2]

Number of Plants

- with FGD = 39
- without FGD = 194

Total = 233

FIGURE 2.5.1 NUMBER OF COAL-FIRED POWER PLANTS ≥ 200 Mw[a] IN DESIGNATED REGIONS OF THE UNITED STATES (Basis Year - 1979)

---

[a] Includes plants with ≥ 80% of power generation in 1977 from coal.

[ ] Coal-fired plants having no FGD systems.

( ) Coal-fired plants having operational FGD systems. One of these plants employing an FGD system is < 200 Mw. Three of these plants employing FGD systems were <80% coal-fired in 1977.

It was noted, however, that the economic implications of any future guidelines or regulations for small plants may be substantially greater than for large ones. Hence, effects were made to ensure that plants below 200 Mw in capacity were considered and that the recommended candidate sites included at least one such plant. Representatives of the American Public Power Association volunteered to try to find additional appropriate <200 Mw plants for the study, but were unable to do so. Smaller plants are often municipal units or publicly owned. The cost of capital for such plant undertakings is different from (and often lower than) that for investor-owned power plants. Environmental and engineering/economic projections on waste disposal based on data from plants recommended as candidate sites in this report could be extended to power plants as small as 25 Mw. In the assessment phases of this project, it will be necessary to remain cognizant of the impact of plant size on engineering, environmental, and cost findings.

Thus, the study focuses primarily on plants with over 200 Mw of generating capacity; the number of such coal-fired power plants in the United States and the percentage distribution in each region are shown in Table 2.5.3 and Figure 2.5.1.

In order to arrive at a reasonable number of candidate sites for each region, a sensitivity to the actual number of coal-fired power plants in each region is required. Further considerations include the following.

- The existence of several types of waste and disposal mode characteristics in one region may require selection of a higher number of candidate sites in that region.
- Major variations in geotechnical and environmental factors within a region may require the selection of a larger number of candidate sites for that region. Similarly, the converse may be true in other more homogeneous regions.
- Projections of future coal utilization and trends in disposal in the United States (discussed in Section 2.4) strongly emphasize the growth in production and utilization of western coal. Hence, it would be appropriate to consider an increased number of candidate sites from the western part of the country and more plants elsewhere that may use western coal in the future. With revised NSPS regulations requiring scrubbing or other sulfur control for all utility (including low-sulfur coal) combustion, the potential attractiveness of western coal as a way to avoid sulfur control in eastern regions has changed. However, western coal is likely to be utilized at an ever increasing rate.

The above factors were considered by the investigators and the targeted number of candidate and back-up sites were chosen in the following sequence.

- Initial screening leading to a preliminary list of sites.
- Closer evaluation leading to about 18 candidate sites and a smaller number of back-up sites.

Table 2.5.3

TARGETED NUMBER OF CANDIDATE SITES FROM EACH REGION

Region Designation	Number of Plants[a,b]	Percent of Total	Targeted Number of Candidate Sites[c]	Targeted Number of Back-Ups (Maximum)[c]
A1	19	8.2	1	1
A2	28	12.0	2	1
B	55	23.6	3	up to 2
C	2	0.9	0	0
D	66	28.3	4	up to 3
E	3	1.3	1	0
F	22	9.4	2	up to 1
G	7	3.0	1	0
H	31	5.2	4	up to 2
I				
J				
K				
L				
M				
TOTAL	233	100.0	18	

---

[a] Coal-fired plants (≥80% of power generated from coal in 1977) which have generating capacities ≥ 200 Mw, with the exception of four plants employing FGD systems with <80% coal firing.

[b] National Coal Association, "Steam Electric Plant Factors (1978)." (Ref. 15)

[c] Pro-rated on the basis of number of plants within each region and a total target of 26 sites, but in addition adjusted due to other considerations (e.g., number of different type disposal modes within each region, future coal consumption projections, etc.)

Source: Arthur D. Little, Inc.

The targeted number of candidate sites in each region is shown in Table 2.5.3. The investigators decided that the group of back-up sites did not need to contain a specific number of sites, but should not exceed eight to ten. It should be noted that these numbers were considered targets and not constraints.

The recommended candidate and back-up sites were expected to provide an adequate data and information base for further evaluations leading to the selection of the final sites for this project.

2.6 ASSESSMENT OF DISPOSAL OPERATIONS

As was emphasized earlier, the overall objective during site selection was to choose a mix of disposal sites across the United States reflecting the following requirements:

- As far as practicable, an adequate number of typical disposal operations in each region were chosen to provide baseline data on the typical effects that could be expected at a variety of such sites.

- In addition, a few sites were chosen to ensure that the potential environmental impacts from such operations could be reasonably bracketed. In other words, it was decided that there should be some sites where the potential impact, given the information available, could be expected to be low and other sites where the potential effects could be expected to be high. It is to be emphasized that all of these judgements were made by investigators experienced in FGC waste disposal working with the available data base.

- It was also necessary to choose a mix of disposal sites so that the engineering/costs of disposal could also be reasonably bracketed. The economies of scale feasible in large disposal operations were to be evaluated. At the same time, sites had to be selected that were small enough so that reasonable projections for fairly small boilers (<200 Mw) are possible. All evaluations were limited to disposal of coal ash and FGD wastes only. If a utility or plant practices co-disposal of FGC wastes with other industrial or municipal wastes, both the environmental and the economic factors involved in such disposal are quite different from those for disposal of FGC wastes alone. These co-disposal situations were therefore recognized to be outside the scope of this project.

The selection process required consideration of the above factors while simultaneously ensuring that a mix of disposal sites be selected where reasonable interpretation of data was possible. For example, it a site had been disposing of fly ash for only nine months, it was unlikely that environmental monitoring of such a site could lead to conclusive results.

To the extent possible, the site selection team remained sensitive to the fact that it would be desirable to select two sites, ideally in different parts of the country and with different geotechnical and climatic conditions, which dispose of analogous wastes by analogous disposal modes. Had this been established as a basic criterion, it might have been mandatory to select three disposal modes and waste types, each with two sites in different parts of the country. However, a closer evaluation of the range of waste types and disposal modes in the country led to the conclusion that such duplication would narrow the total field and leave some major data gaps on certain important waste types and disposal modes. Therefore, while the desirability of analogous operations in different areas and conditions was acknowledged, it was not laid down as a basic criterion.

Based on the issues discussed above, a rating system for the disposal practice assessment was established. It is presented in Table 2.6.1. The important considerations involved in each criterion are briefly described below.

2.6.1 Elimination Criteria

Two basic criteria were established which eliminated a plant from further consideration.

- Plants with disposal sites less than two years old were eliminated. If a plant had several sites, each site was considered separately. It was decided that if a disposal site was less than two years old, it would not provide an adequate base for environmental monitoring.

- Plants that sold 50% or more of their ash output were eliminated. If a plant sells a substantial part of its ash output, the type of waste sent to disposal is likely to be quite variable. Ash utilization is growing (10) but at present only a fraction of total ash generated is utilized. However, if such a plant had an FGD system and if the FGD wastes were disposed separately, then it was decided that such FGD disposal would be evaluated on its own merits. (Note: There were not such sites.)

The above criteria led to the elimination of 30 plants out of a total of 176 plants evaluated. It a plant was not eliminated based on the criteria described above, it was then subjected to the rating criteria described below.

2.6.2 Rating Criteria

2.6.2.1 Waste Variability

FGC wastes obtained from power plants can vary due to a number of factors. Important ones include:

Table 2.6.1

ASSESSMENT OF DISPOSAL OPERATIONS

ELIMINATION CRITERIA (noted by an 'X')

- Ash Selling: > 50 wt. %
- Disposal Site Age[a]: < 2 years

RATING CRITERIA	CRITERIA RATING
• Waste Variability Considerations	
- Plant Type: base ; peak	1+ ; 0
- Coal Purchase: contract ; spot	1/2+ ; 0
• Disposal Practices	
- Classification: typical ; atypical	1+ ; 0
- FGD System Operation: ≥ 2 years; < 2 years	1+ ; 0
• Mitigative Engineering Practices	
- Liners: present ; not present	1/2+ ; 0
- Pond Effluent Recycle: practiced ; not practiced	1/2+ ; 0
- Dry Handling, Dewatering, Co-disposal or Stabilization: practiced ; not practiced	1/2+ ; 0
TOTAL:	5+ ; 0

---

[a] Disposal site was also considered to be < 2 years old if site included the disposal of FGD wastes and FGD system was < 2 years old.

X = Eliminates plant from further consideration.

- Whether the boiler and the plant are baseload or peaking plants. For the purposes of this project, it was felt that selection of plants more commonly used in baseload work would provide a steadier stream of wastes with more manageable ranges of variability. If a plant was used for both baseload and peaking, it was regarded as a baseload plant.

- Characteristics of the coal which can affect the waste's characteristics. While this is difficult to quantify, one facet of this is purchase of coal on the spot or contract market. Data are available from published sources(20) outlining the typical practice of a plant. Plants that more often purchase coal on a contract basis are more likely to have preferable (understandable) disposal sites for evaluation purposes under this project. Again it should be remembered that the evaluations will provide data which can be used in assessing and providing recommendations for all types of disposal sites.

2.6.2.2 Disposal Practices

In each region an assessment was made of the various modes of disposal practiced and a matrix was developed. From the matrix, it was then possible to determine if the disposal practice at a particular site was typical of the region or not. To the extent possible, emphasis was placed on selecting typical disposal sites.

2.6.2.3 FGD System

As of mid-1979, there were only about 39 operating FGD systems in the United States and a much smaller number with operating disposal experience of two years or more. Hence, in the case of plants with FGD systems, an addition factor, namely the presence of the system, was incorporated into the rating.

In some cases atypical disposal operations were ultimately selected when it was clear that they offered an important environmental bracket (potentially low or high impact).

2.6.2.4 Mitigative Engineering Practices

Site selection was not made on the basis of choosing only plants that practice or do not practice engineering/technology mitigative measures; the objective here was to ensure the presence of the criterion so that when all the candidate sites were selected, a total mix of disposal practices involving both presence and absence of mitigative engineering/technology measures was obtained. Important mitigative measures can be broadly placed in three categories.

- Liners that were actually placed for mitigative purposes. For example, if a utility places a three-foot layer of bentonite clay below a pond, it is an engineering/technology mitigative practice. If the site is underlain by 10 feet of clay to begin with, such mitigation is the result of original site selection and was not considered a mitigative practice for purposes of this study.

- Pond effluent recycle. This was considered an engineering mitigative practice and considered a favorable factor.

  This rating factor was included since it is believed that FGC waste pond effluent recycle is going to be practiced more widely in the future.

- In terms of mobility of dissolved constituents by leaching into ground and surface waters, minimization of hydraulic head on wastes at the disposal sites is a favorable factor. This can be achieved by dry handling of ash, dewatering of FGC wastes, or co-disposal or chemical stabilization of FGD wastes. A whole range of technology is available and many plants practice it. At the same time there are several plants, for example, in Region A2 (Piedmont and Coastal Plains) where the typical practice does not involve such dry handling procedures. This rating factor was included so that on the national scale a range of disposal practices with or without such mitigative measures was obtained.

Many aspects of the rating system were not able to discriminate between plants in certain regions. For example, in Region A2 the mitigative measures were not a criterion which discriminated between plants because many plants do not employ such measures. In other regions of the country, however, a mix of plants was obtained that do employ mitigative practices, thereby giving a range of sites.

Baked

2.7 HYDROGEOLOGIC CONSIDERATIONS

Leachate movement from FGC wastes into groundwater is a key mechanism for transport of dissolved constituents. Hence a major step in the site selection process was to evaluate the hydrogeological & geotechnical characteristics of a site. This evaluation was designed to identify overwhelming geological or geotechnical constraints. These constraints include considerations of climate, general bedrock geology, surficial soil characteristics, and groundwater flow conditions on the sites. In this section, these constraints are described with reference to groundwater flow. However, some of these also have non-point effects on surface waters and are considered from that perspective in Section 2.8.

To some extent, it would be possible to carry out geotechnical investigations on almost any site. It is, therefore, somewhat difficult to envision geological and geotechnical constraints which would totally eliminate a particular site from consideration. On the other hand, the ability to get data on a particular site of sufficient quality and relevance within one year of monitoring can be severely limited and can indicate that a particular site should not be selected for study. Table 2.7.1 shows the hydrogeologic ranking used in candidate site selection.

It was considered desirable to investigate climatological, geological, and surficial soils characteristics in a general way during the candidate site selection process. Although it would have been highly advantageous to be able to evaluate a particular site quantitatively with respect to geological and geotechnical aspects during this process, data on surficial soil, groundwater flow conditions, and geological conditions tend to be extremely site-specific. Data on climatological factors are also site-specific but to a lesser extent. Because of this, the hydrogeologic and geotechnical evaluation of sites actually involved two steps. First, the generalized picture of geological and geotechnical conditions on a site was obtained through reference to geological maps and maps showing surficial soil conditions and climatological factors. Second, if a site was identified for further consideration, more detailed site-specific investigations were made to fully characterize the site geological conditions, the water flow regime, and the climatological factors. In practice, site-specific information has sometimes been available for early consideration from such sources as the VERSAR report.(1)

In general, climatological factors are important to the selection process in that the migration of pollutants out of a waste disposal site will be influenced significantly by rainfall and evaporation at the site.

The infiltration of water into the subsurface layers at a site is dependent on the soil and rock conditions at the site. It is also dependent on the balance between precipitation and evaporation at the site. A general measure of precipitation at a particular site can be obtained from weather bureau records on measured precipitation. Figure C-5 in Exhibit C shows a simplified representation of total annual rainfall in the United States.

USE THIS SHEET FOR REPORT TYPING 8 1/2 x 11

TOP

7

Table 2.7.1

HYDROGEOLOGIC RANKING SYSTEM FOR CANDIDATE SITE SELECTION

Rating	Some Typical Characteristics
A	Tight geologic basement, pervious sediments above basement, relatively uniform geology. → Easy interpretation of groundwater system
B	Relatively intact pervious bedrock, some crossflow between soil and rock, slowly pervious soils. → Problems in interpretation of groundwater system.
C	Complex basement rock system, irregularly jointed/voided bedrock, thin, irregular impervious soils over bedrock. → Very difficult to impossible to interpret groundwater system.

Note: A rating of C - indicates that a site is almost impossible to interpret. Sites with this rating are given an "X" to indicate their elimination from further consideration.

Source: The University of Louisville

To Line to End of Typing Area

For Page Numbering

Precipitation is extremely seasonal in certain portions of the United States, where wet and dry seasons are experienced. In other areas, such as the Pacific Northwest, precipitation is a much more regular event and occurs during a high percentage of the time. In areas where precipitation is regular, its intensity at any one time is not usually greatly in excess of the intensity experienced at other times. In regions where precipitation is seasonal, however, its intensity is extremely variable. For example, many portions of the United States experience precipitation in connection with the movement of frontal systems through the area. Precipitation occurs during thunderstorms and the intensity of rainfall may be extremely high for a very brief period of time. During such a period, the surficial soils at a site will absorb water at a rate and to a degree consistent with their physical characteristics, the groundcover at the site, and the moisture content of the soil at the time of the precipitation event.

The infiltration of water from a precipitation event into a subsurface system at a disposal site is a complex phenomenon. Water may fall at a rate which is in excess of the ability of the soils to absorb the water. A portion of this water may run off the site and a portion may be temporarily stored in depressions on the site or held by vegetation growing on the soil surface. Other climatological factors then begin to influence the situation. If the rainfall in a particular area is highly seasonal and is extremely intense during short periods of time, runoff may be very high. Additionally, if the general situation at a site includes low relative humidity, strong prevailing winds, high temperatures, and a large percentage of available solar energy, evaporation may be extremely high. In some cases, climatological factors will combine to create a situation in which potential evaporation may far exceed precipitation. Also, vegetation may act to transpire moisture from the soil system back into the atmosphere and evaporation and transpiration together may exceed precipitation. Vegetation at a disposal site is rare during disposal operation; however, many operators practice some form of reclamation after termination of operations on each section of a site.

The complex interaction among evaporation, transpiration, and precipitation precludes any simplified evaluation of climatological factors at a site. However, information such as that shown in Figures C.3 and C.5 through C.7 in Exhibit C on temperature, annual precipitation, evaporation, and runoff rates for given areas of the United States is useful in indicating areas where a testing and evaluation program could encounter difficulties. For example, evaluation of groundwater flow conditions at a site where evaporation far exceeds precipitation could be costly and yield poor results. The net evaporation could reduce infiltration of rainfall into the subsurface layers to a minimum and the migration of pollutants from waste disposal areas could be eliminated. This is a factor that requires special consideration in the west where such conditions prevail.

Special considerations also apply in areas of the country where precipitation is very high. For example, in parts of the Pacific Northwest and the Appalachian Mountains precipitation can exceed 175 cm (70 in.) of rainfall per year. In such areas, infiltration of water into the subsurface system is likely to occur in great amounts and sites located in such areas therefore are likely not to reflect conditions existing at the majority of power plants in the United States. These may represent extremes from an impact assessment viewpoint.

In addition to limiting pollutant migration, rainfall and evaporation are important parameters in the designation of comparison sites. If an attempt is made to locate more than one waste disposal area which reflects a popular waste disposal technology, it is advisable to attempt to locate comparable sites in areas where rainfall and evaporation conditions are very different to bracket varying site conditions.

Frost action is another important climatological factor. Waste disposal operations are carried out in the open air and in some cases include the mixing of materials to obtain a cementation or fixation reaction. Such reactions generally are retarded by temperatures below 0°C (32°F). Figure C.4 in Exhibit C shows contours of maximum frost penetration for the United States. These contours represent maximum recorded frost penetration levels during winter seasons in the last one hundred years. In general, average penetration of frost in soil systems is considerably less than the penetrations shown in this figure. Although frost action is not the type of climatological factor which would eliminate a particular site from consideration, its consideration would be relevant in evaluating the possible detrimental effects of frost action on fixation and cementation reactions in waste disposal areas where such reactions are expected. Detrimental effects of frost action on fixation could be significant wherever maximum frost penetration exceeds 100 cm (40 in.) during a winter season and wherever severe maximum frost penetration exceeds 250 cm (100 in.) per year.

In addition to climatological factors, basic geotechnical factors can favor or constrain the selection of a site. For example, if the geological conditions at a site are an extremely confused sequence of rock units occurring at very shallow depths beneath a disposal area, the interpretation of data obtained from groundwater wells may be extremely difficult, if not impossible. For this reason, sites with geologic complexity that would preclude interpretation were not selected. Very complex geological conditions can be expected in mountainous areas where orogeny has produced a distortion and displacement of rock units. As an example, selection of a site in the area of Atlanta, Georgia, may be inadvisable in that metamorphism of the basic rock units in that area has been extreme and the rock units have been displaced and disordered by shifting movement in the crust. It should, however, be emphasized that every effort will be made to develop recommendations from this assessment program that will be applicable to all sites, including those with complex geology.

Subsurface conditions may also be extremely complex at a site. If a site is overlain by a great thickness of surficial soils, the complexity of the underlying bedrock conditions may not be as influential as at a site where only shallow soil cover exists over rock. However, if the soil cover consists of residual soils developed from the in-place weathering of the underlying rock units, the surficial soil conditions may be as complex as the underlying rock conditions and interpretation of geotechnical and water quality data from such a site may be very difficult. Ideally, sites should be selected in areas where very thick deposits of very uniform, homogeneous, surficial soils are found above essentially impervious, very regular homogeneous bedrock units. It is, however, unrealistic to expect to find such conditions in the United States, or anywhere else in the world. Therefore, the approach during site selection was to avoid selection of sites in areas where geologic conditions are known to be extremely complex. The evaluation of sites with regard to the geologic conditions can be very general during the candidate site selection process, and a detailed subsequent examination of the conditions at particular sites was required to disclose the complexity or uniformity of their geological conditions.

It was also considered advisable to avoid sites where surficial soil conditions or characteristics would limit or make difficult the interpretation of data obtained. Surficial soil conditions tend to be very site-specific. Therefore, evaluation of surficial soil characteristics requires the detailed inspection and exploration of the soils on a site. Soil conditions in various areas of the United States were considered in a very general and approximate way during candidate site selection. For example, it was considered advisable to consider carefully and, if necessary, eliminate from further consideration young sites located in areas where the predominant soil types consist of very fine-grained clayey soils. The existence of deep deposits of very fine-grained soils beneath a disposal area would severely limit the migration of water through the site, making obtaining data on the flow of water very difficult and obtaining data on the migration of chemical species almost impossible. Also, fine-grained soil materials quite often contain colloidal-size particles of clay minerals which have significant absorptive properties and which will react to attenuate chemical species being transported by groundwater. Very old disposal sites with such soil may still be acceptable. Although it would be advantageous to be able to evaluate the attenuation of chemical species from waste disposal areas, selection of a young site where very thick deposits of clay are found beneath a disposal area may prevent any evaluation of such attenuation mechanisms simply because groundwater flow in such zones is very slow and the evaluation of species migration may be almost impossible. A site with a thin layer of clay soil interspersed with layers of more coarse-grained, more pervious soils may furnish an opportunity for more meaningful evaluation of soil attenuation mechanisms. Similarly, older sites (+15 years or more), even if underlain by clay, may offer an opportunity to study such conditions.

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

During the preliminary stage of site selection, it was appropriate only to attempt to delineate areas in the United States where subsoil conditions would tend to limit the interpretation of data on groundwater flow and pollutant migration. Figure C.2 in Exhibit C delineates, in a general way, the soil conditions to be found in the United States.

As mentioned previously, sites underlain by thick layers of clayey soils may be marginally useful because of the very slow groundwater movement through such soils. On the other hand, extremely variable soil conditions may make it very difficult for investigators to interpret groundwater flow data and quality data. The information on general soil conditions throughout the United States shown in Figure C.2 of Exhibit C can be utilized only in a preliminary way to indicate that certain areas should be included in the testing program. Areas underlain by uniform thick deposits of coarse-grained soils make for rapid infiltration and flow of groundwater.

In addition to the climatological, geological, and surficial soil factors, some other geotechnical factors were given consideration in the evaluation process. These factors, however, can only be evaluated properly on the basis of rather specific data collected when sites are visited. The types of information needed included the existence of groundwater wells near the proposed waste disposal test location, the utilization of groundwater (e.g., heavy pumping) near a site, and the existing contamination of the groundwater. All other things being equal, the existence of groundwater wells on a particular site would tend to favor the inclusion of such a site in the program.

If a large number of groundwater supply wells (i.e., water used for some purpose) as distinct from groundwater monitoring wells already exist near a site, the existence of such wells may facilitate obtaining and interpreting data on groundwater flow patterns. If the groundwater is utilized to a high degree, the groundwater flow patterns may be severely affected. On the other hand, if the aquifer beneath a site has a high yield of groundwater, significant use of that groundwater may not lead to severe depression of the groundwater table. Such use may assist in delineation of the groundwater flow patterns and detection and quantification of contaminant released from waste disposal facilities. Alternatively, such local flow situations may make the interpretation of groundwater flow information for a particular site difficult. Therefore, sites where groundwater utilization was known to be high were carefully studied prior to selection during the candidate site selection process.

Existence of contamination of unknown origin at a site would almost preclude its inclusion in the program. If chemical species in large numbers and high concentrations already exist in the groundwater beneath a site, it may be almost impossible to detect and quantify the presence of materials emerging from a waste disposal area. For this reason, sites where other sources of confounding groundwater contamination make source assessment infeasible were excluded from consideration. However, in many cases, this could only be fully evaluated during or after site visits.

For Page Numbering

2.8 OTHER SITE SELECTION FACTORS

Section 2.7 described hydrogeological constraints considered in the site selection process. The focus was on groundwater flow-related mechanisms of impact. However, the overall objective of this project also includes evaluation of effects on surface water from non-point sources and the use of potentially mitigative design, management, or control practices.

Both groundwater issues and issues of non-point impact on surface water quality have several dimensions.

- There has been regulatory emphasis on drinking water quality as measured in terms of the Primary Drinking Water Standards. For utility wastes, this requires careful consideration of the potential for migration of significant amounts of concentrations of several trace metals sometimes associated with these wastes (especially fly ash).

- Major constituents of some of the waste streams (i.e., unstabilized FGD wastes) can include dissolved salts, such as chlorides and sulfates, as well as such metals as iron. The potential impact of leachates of these materials, some of which have been the subject of proposed Secondary Drinking Water Standards, provided a basis for further considerations in the site selection process.

- The issues and standards associated with the protection of surface water uses (e.g., for support of aquatic life) have been considered as part of the review of the sites suitability for study of surface water impacts of non-point source drainage.

This section outlines the method used for incorporation of other considerations into the site selection process. A principal overall objective of these considerations was to ensure that a representative mix of candidate sites would be available for further evaluation. This representative mix was intended to include examples of potential extremes of positive and negative environmental impacts, and also of potentially "typical" impact situations between the extremes.

Given the priorities for the considerations outlined in Section 2.2.1, the following additional information was developed for each disposal operation evaluated.

- A brief description of each plant site, including variations among disposal sites at the plant.

- A series of rating factors covering all site selection factors other than engineering and hydrogeologic. These factors were designed to promote the identification and consideration of sites that were suitable for the investigation of non-point surface water impacts, mitigative control practices and other effects. Further, to aid in the development of a broad data base for the environmental assessment (i.e., to minimize the need for extrapolation), the rating factors were designed to promote consideration of sites that would provide data on the extremes of potential positive and negative impacts for the full range of disposal practices and environments; at the same time, the application of these factors also served to identify situations where more "typical" (or less extreme) impact situations might prevail. This served as a mechanism to highlight and assist in selecting a mix of typical and extreme sites.

The engineering and hydrogeologic rating factors focus on the suitability of a site for monitoring; the other site selection rating factors highlight this factor and potential opportunities to study effects. As such, this rating based on other factors is to be viewed differently from the engineering and hydrogeologic ratings. In no case was a plant site eliminated because of ratings in this third group (other site selection factors).

These other site selection rating factors fall into two basic categories. First are regional/generic factors, which were developed and applied on the basis of information available on area environmental conditions, largely from the general literature. Within this category are included climatic and selected regional soils data, along with data on reported critical regions for groundwater and surface water utilization.

The second set of factors is site-specific and was accounted for on the basis of the information available on the individual disposal operations. These factors include:

- Site setting, with two subsidiary considerations
    - disposal operation age and substrate relative to groundwater, and
    - proximity to surface water
- Mitigative controls, with three subsidiary considerations
    - dewatering or dry disposal of fly ash or FGD waste,
    - use of a placed liner, and
    - chemical pretreatment of FGD waste
- Baseline environmental information
- Other study opportunities and
- Complicating factors.

Each of these rating factors is described in detail below.

2.8.1 Regional/Generic Factors

In this category, plants (or specific disposal operations) received either a "+" if they satisfied the criterion, or a "0" if the criterion was not satisfied, therefore not applicable. Because open literature data for the whole country was used, data was usually available for this part of the ranking.

Climatic Factors

Three types of climatic factors were rated:

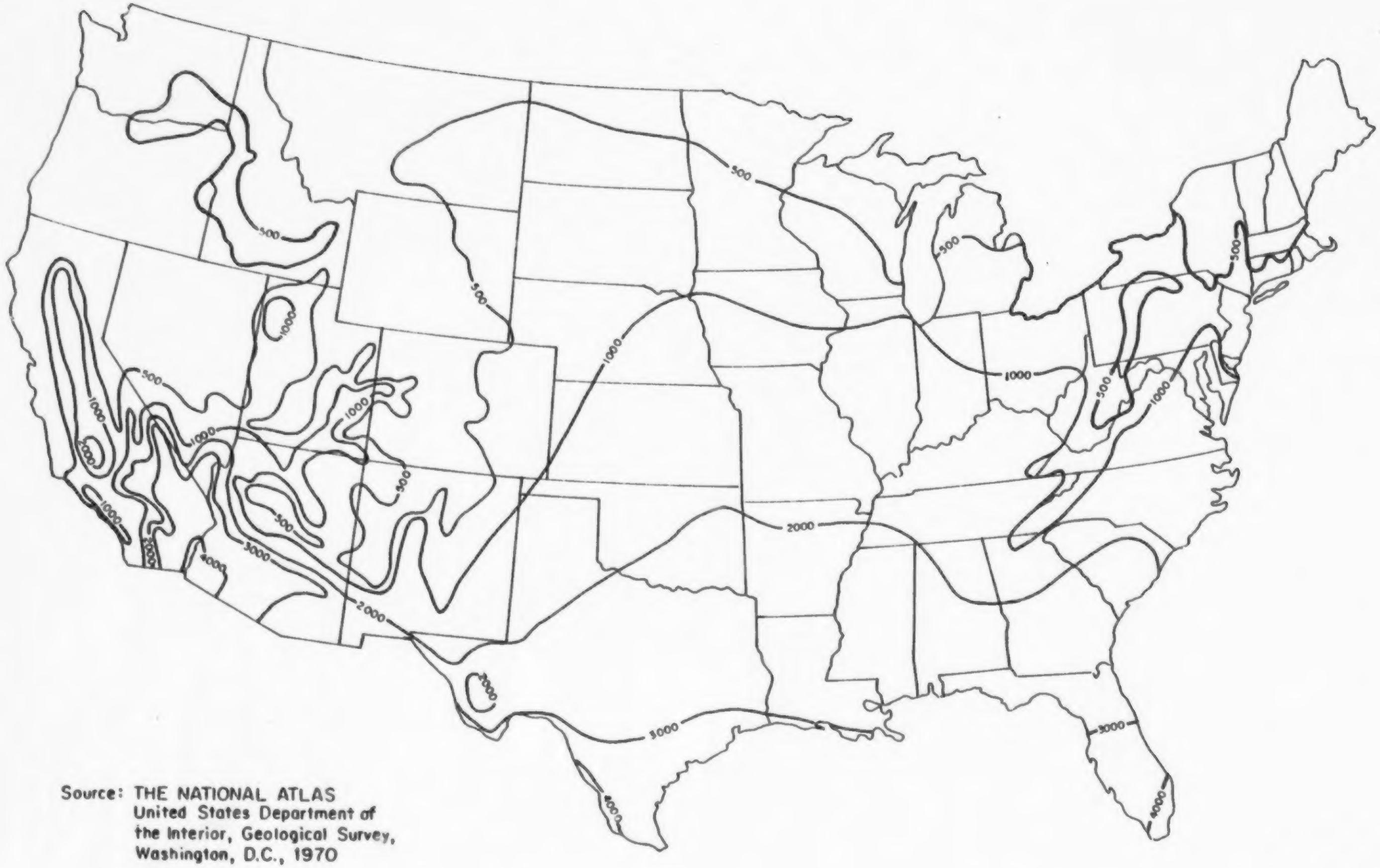
- Temperature extremes were considered important because of their effect on waste behavior in the disposal environment. A "+" rating was given to plants located in areas where the combination of cooling degree days and heating degree days exceeded 7000 degree days annually. Figures 2.8.1 and 2.8.2 show the annual average cooling degree days and heating degree days for the United States that were used for the ratings.

- Precipitation extremes were considered important because of their influence on the mass transfer of contaminants in the disposal environment. A "+" rating was given to sites occurring in regions that experienced less than or equal to 40 cm (16 in.) of gross precipitation per year, or greater than or equal to 120 cm (48 in.) of gross precipitation per year. The map shown in Figure C-5 in Exhibit C was used in conjunction with site-specific data from the VERSAR report(1) to apply this criterion. Where discrepancies or ambiguities existed, site-specific data prevailed.

- Freeze/thaw conditions were also considered because of their importance to the creation of physical irregularities in waste deposits and thereby to the promotion of contaminant migration. A "+" rating was given to sites occurring in regions with less than or equal to 150 frost-free days per year. Figure 2.8.3 illustrates the distribution of these conditions used for the ratings.

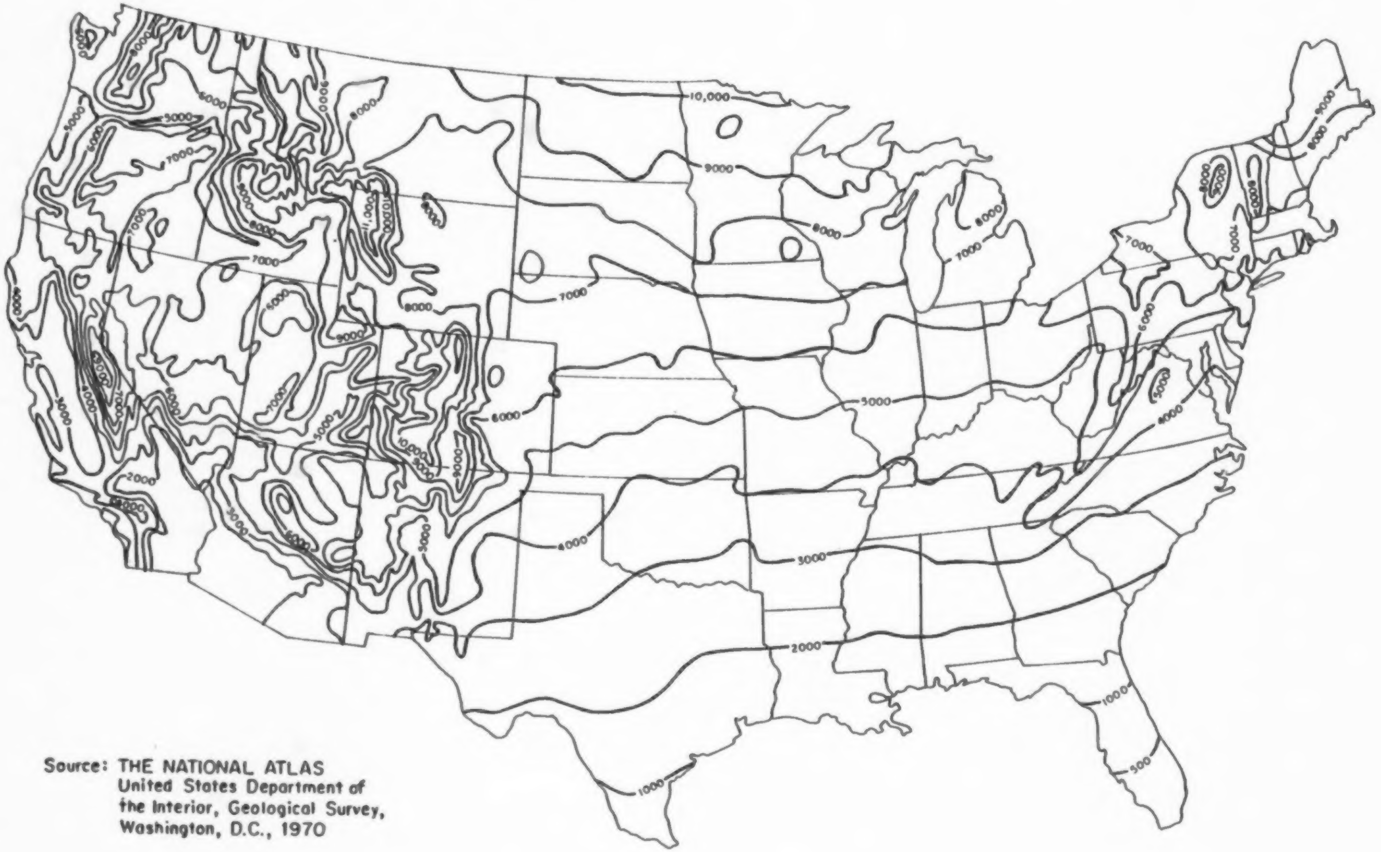
Regional Contaminant Migration Factor

In regions where there is a combination of excessive precipitation and relatively pervious coarse soils, one would expect the greatest probability of contaminant migration from waste deposits. Because of the need to determine this type of boundary condition for the environmental assessment, a "+" rating was given to plants located in areas where $\geq$ 120 cm (48 in.) precipitation and coarse coastal plain soils coexist. Figure C-2 in Exhibit C shows the regional soils map used along with Figure C-5 to apply this criterion.


500
500
500
500
500
500
500
500
1000
1000
1000
1000
1000
1000
1000
1000
1000
2000
2000
2000
2000
2000
2000
3000
3000
3000
4000
4000
4000

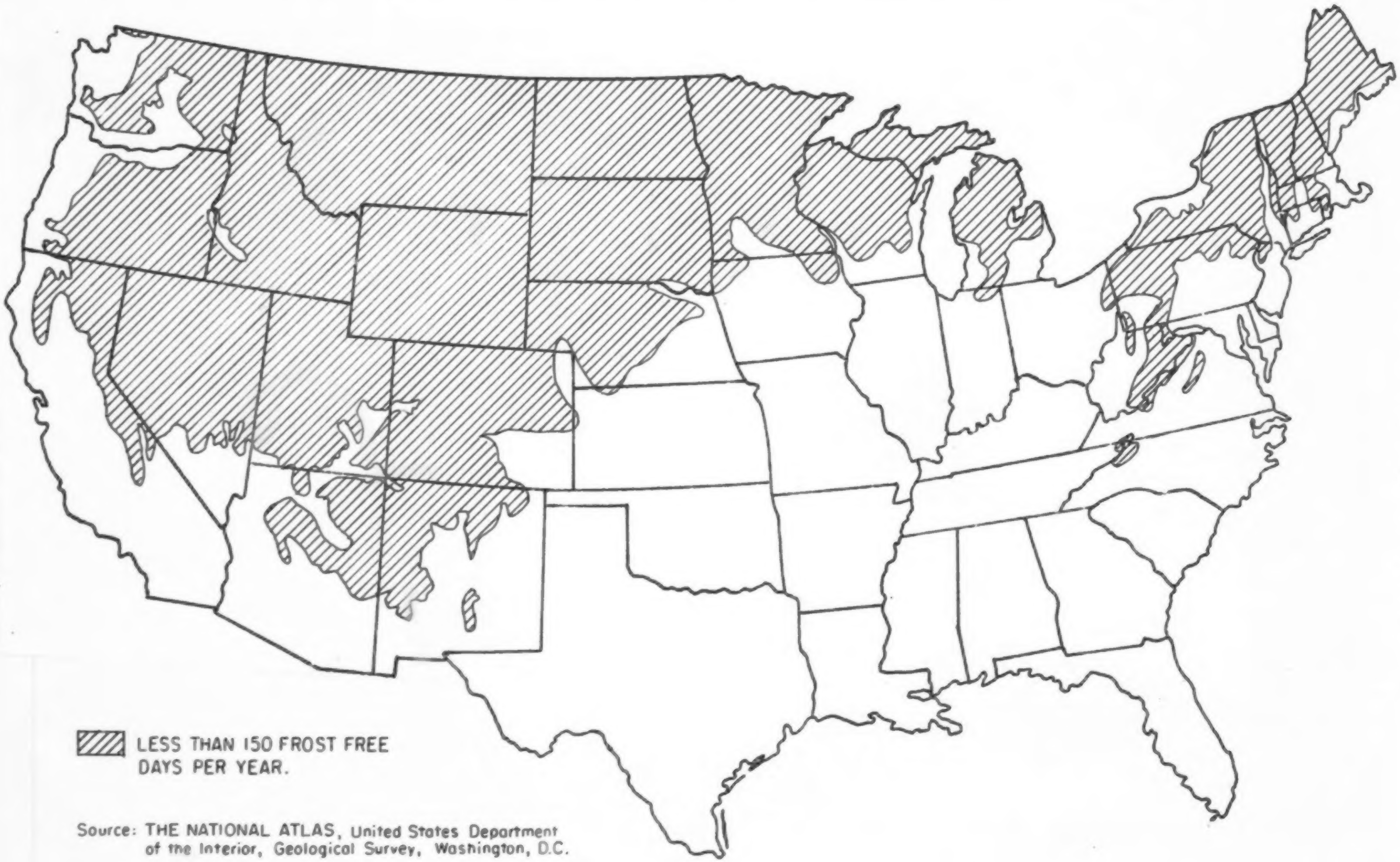
Source: THE NATIONAL ATLAS
United States Department of
the Interior, Geological Survey,
Washington, D.C., 1970

FIGURE 2.8.1 MEAN ANNUAL COOLING DEGREE DAYS


10,000
9000
8000
7000
6000
5000
4000
3000
2000
1000
500
11,000

Source: THE NATIONAL ATLAS
United States Department of
the Interior, Geological Survey,
Washington, D.C., 1970

FIGURE 2.8.2 MEAN ANNUAL HEATING DEGREE DAYS



▨ LESS THAN 150 FROST FREE DAYS PER YEAR.

Source: THE NATIONAL ATLAS, United States Department of the Interior, Geological Survey, Washington, D.C. 1970.

FIGURE 2.8.3 MEAN ANNUAL FROST-FREE PERIOD

Water Use

Two subsidiary categories of water use were rated.

- Groundwater use was of considered importance. A site was given a "+" if groundwater utilization was reported to be critical in the region in the Second National Water Assessment.(21) The shaded areas in Figure 2.8.4 represent the areas of significant overdraft where this criterion applied.

- Surface water use was considered of special importance if the area was reported to be in a critical state of surface water utilization in the Second National Water Assessment. A "+" was given to sites located in such areas. Figure 2.8.5 is a map showing the shaded areas where this criterion applied.

All of the above rating criteria were used to allow highlighting of extreme and typical conditions in the categories mentioned. They do not relate to any actual impacts.

2.8.2 Site-Specific Factors

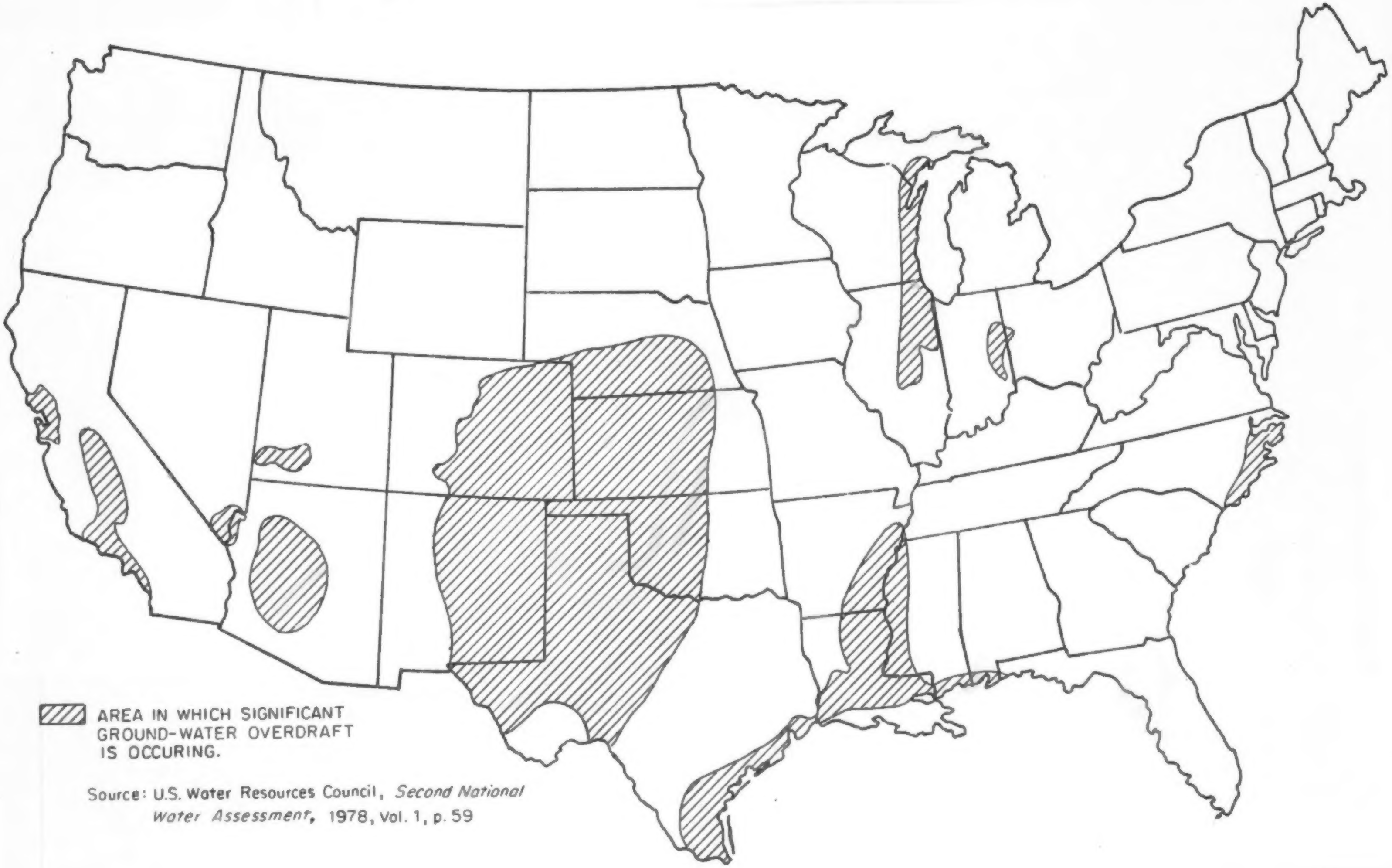
Four types of ratings were applicable to each of the site-specific factors. These were: "+", given if a favorable study criterion was met; "-", given if an unfavorable study criterion was met; "0", given if the criterion was inapplicable; or "NA", given if the information was not available for the disposal operation or site under consideration.

Site Setting

Two components were looked at in this category.

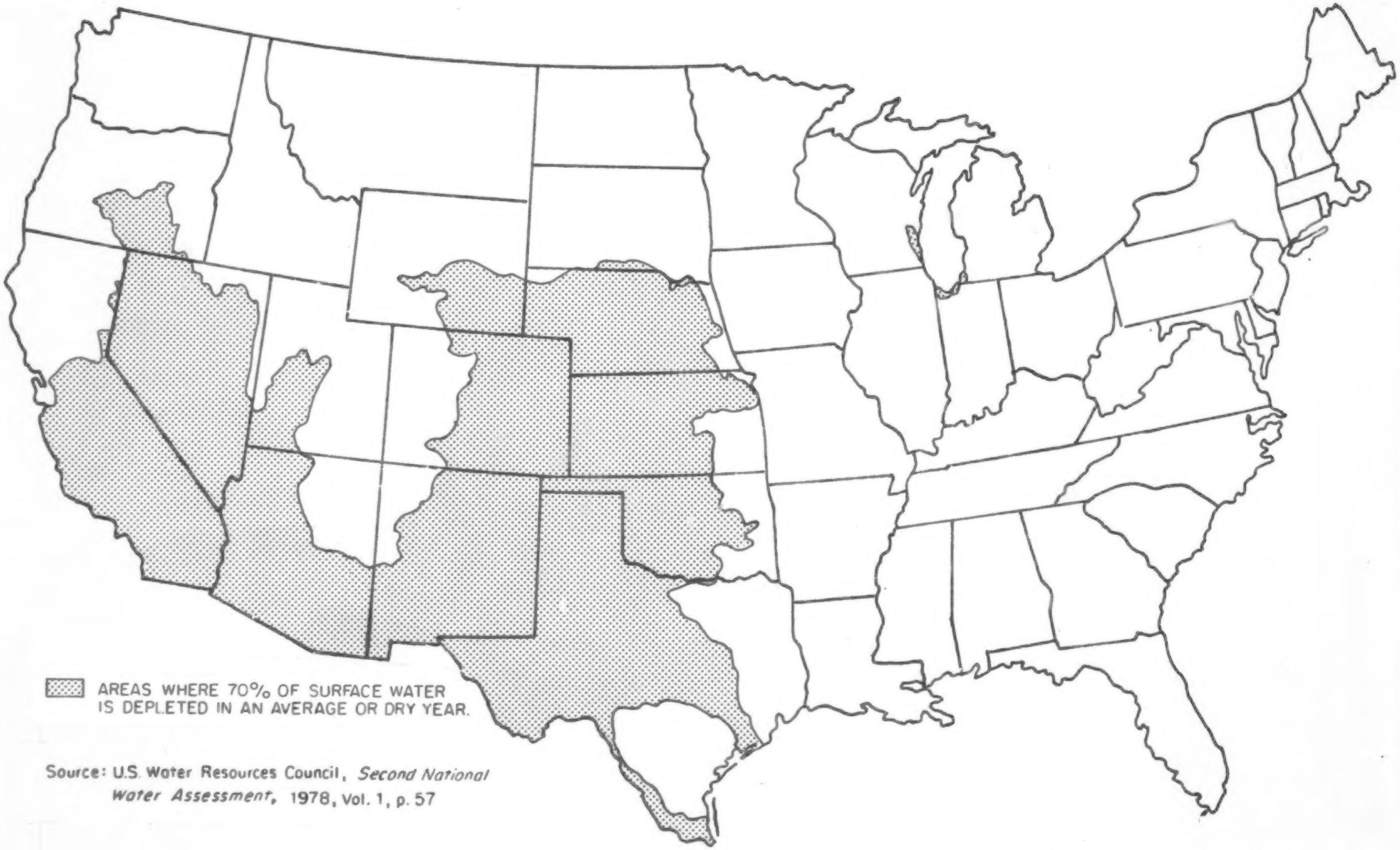
- Combination of site age and substrate relative to groundwater. In order to account for likelihood of contaminant migration beyond the immediate vicinity of the waste deposit, the disposal operation was given a "+" if it was at least one year old for every 1.5 m (5 ft) of clay or silt between the waste and the reported water table or at least one year old for every 150 m (500 ft) of coarse sand or gravel between the waste and the water table.

  A "-" was given if this criterion was not satisfied, or if rock layers existed in the potential migration path. Note that site-specific data used to apply this criterion would override any conflicting data available for the regions from the generalized soils maps (Figure C-2 in Exhibit C).


▨ AREA IN WHICH SIGNIFICANT GROUND-WATER OVERDRAFT IS OCCURING.

Source: U.S. Water Resources Council, *Second National Water Assessment*, 1978, Vol. 1, p. 59

FIGURE 2.8.4 AREAS WITH SIGNIFICANT GROUND-WATER OVERDRAFT



▨ AREAS WHERE 70% OF SURFACE WATER IS DEPLETED IN AN AVERAGE OR DRY YEAR.

Source: U.S. Water Resources Council, *Second National Water Assessment*, 1978, Vol. 1, p. 57

FIGURE 2.8.5 AREAS OF INADEQUATE SURFACE WATER SUPPLY

- Proximity to surface water was considered important to the assessment of non-point source surface water impacts. If a disposal operation was known to be in direct proximity to a surface water body, in relation to its age and surroundings it was given a "+". In most cases, information on this factor was unavailable when the preliminary rankings were developed. A "+" was not given when other facilities or activities (e.g., the generating station) were known to lie between the disposal site and the water body.

Mitigative Controls

- Dewatering or dry disposal of fly ash or FGD waste was given a "+" because of the potential for decreased head and contaminant migration under such circumstances.

- A placed (imported) liner was also given a "+". Extra credit was not given to sites developed in "natural" liners, such as clay soils.

- Treatment of FGD waste, usually by the addition of lime and fly ash, among other additives, was considered of special importance because it represents a technology reported to influence the nature of environmental impacts of the leachates. Therefore, a "+" was given to sites where this practice was employed.

Baseline Information

The timeframe for sample collection in this study serves as a recognized constraint on the extent to which the data can be used for trend assessment. Certain types of baseline information will assist in developing relevant, cost-effective test plans and may provide further interpretive reference points for trend assessment in the study program. Thus, in order to make maximum use of the data collected in the study timeframe, a rating criterion was included that would credit sites where potentially relevant baseline information was reported to be available.

One form of potentially relevant baseline data is information on the nature of the waste streams under study. This type of information was available in one of three forms: (1) water balance information describing the volumes of bottom ash and fly ash transport streams; (2) percentage breakdowns of waste landfill composition; and (3) the "priority pollutants," including trace metals, known to be present in plant waste streams. Disposal operations were credited with one "+" where any or all relevant forms of this data was available. For priority pollutants, operations were credited when information indicated that measured data was available on at least four such

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

contaminants. A second "+" was credited to those relatively few disposal operations where previous special baseline studies or monitoring efforts appeared likely to exist. For example, this included operations where special studies of miscellaneous ash pond influents had been performed and operations where developed monitoring wells were reported to exist.

10 Lines to End of

Other Study Opportunities

This category was used to add information of a positive nature to the ranking system where special circumstances prevailed. For example, if some of the issues of overall lower priority (e.g., land use or biotic impacts) were considered likely to be of special relevance at a given site, it was given a "+". Pond sites practicing recycle received a "+" because of the potential to observe the results of conserving the mass of contaminants in the disposal area for long-term leaching. Sites with FGD systems and wastes were given a "+" in this category because of the opportunity to evaluate potential contaminant impacts unique to FGD wastes. Sites with designated future land uses that could be affected by waste stability and/or contamination were given a "+", as were sites operating in active or abandoned surface mines. A "+" was also awarded to any disposal operation where the waste was reportedly 100% of a given type; i.e., fly ash, bottom ash, or FGD waste, because of the potential opportunity to place individual waste impacts in perspective.

Complicating Factors

Factors that could prevent the acquisition or interpretation of meaningful monitoring data were considered negatives in the site selection process. These included the presence of >10% miscellaneous influents in disposal ponds or disposal facilities too close to other sources of potential contamination, like other waste disposal operations or major point-source discharges. The use of an interim disposal step, such as ponding prior to landfill, was considered a potential complicating factor. A maximum of 2 "-" was given in this category, depending on the number and extent of potential complications.

10 Lines to End of Typing Area

It is important to note that these other site selection rating criteria were applied to each disposal operation at the various sites. Therefore, plants with more than one disposal operation can have more than one rating. Table 2.8.1 shows the rating format that was used to assemble this information for each region.

For Page Numbering

Ta 2.8.1

TABLE 2.8.1

OTHER SITE SELECTION RATINGS FOR DISPOSAL SITES

REGIONAL/GENERIC FACTORS

SITE-SPECIFIC FACTORS

Plant & Utility	Total Rating (+ and -)	Climate			Contaminant Migration Factor (Climate and Soils) (+)	Water Use		Setting		Mitigative Controls			Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
		Temp. ≥7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤150 Frost-Free Days (+)		G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)			

2.9 UTILITY COOPERATION

The previous sections of Section 2.0 have outlined important considerations in the site selection process. In addition to these, certain key factors which are difficult to quantify have come into play.

Utility cooperation was recognized to be very important in the site selection process. Whatever the nature of the technical considerations leading to site selection, the success of characterization and environmental monitoring at a site is critically dependent on cooperation between the entities which own and manage the sites and the EPA contractor. Because of this, it was decided to utilize several opportunities and methods to determine potential utility cooperation:

- The Advisory and Technology Committees formed for this project are composed of representatives of utilities and utility trade associations (Exhibit B lists membership). Discussions with these organizations have given us a preliminary indication of the likelihood of cooperation by individual utilities and have outlined some areas of concern to the utilities.
- Certain utilities have indicated to EPA that they would be very willing to cooperate on this program. One such example is the Tennessee Valley Authority.
- A preliminary indication of utility cooperation was provided in the VERSAR data sheets.

No site was eliminated in the site selection process on the basis of a potential lack of utility cooperation. This will become important as further evaluation of the candidate site proceeds.

Additionally, after the candidate and back-up sites were selected, utility cooperation was a major factor in further evaluation. In all cases, the utilities involved provided input to the evaluation plan at each of their sites prior to and during the field studies. Data gathered were shared with these utilities. In a real sense the utilities were active participants in the Project.

3.0 CANDIDATE SITES - REGIONAL SELECTION

The candidate site selection process was conducted by members of the site selection team in a series of iterative evaluations. Certain considerations in the site selection process are noted below.

- The division of the country into 14 broad regions as a discussion and management tool. As described earlier in Section 2.3, the regions include a wide variety of both inland and coastal areas. As such, they represent a full range of hydrogeologic and climatic conditions.

- After selecting a targeted number of sites in each region, the selected ones were iteratively rated and a list of candidate and back-up sites was recommended.

- The overall objective was to choose a mix of typical sites and sites to bracket potential environmental effects.

- The candidate site selection process was primarily focused on choosing suitable plants for each of the major generic types of wastes and typical modes of disposal in hydrogeologically understandable locations. This was done, as far as practicable, given the original limit of 12 final selected sites (which was later returned to 6) and the target of about 18 candidate sites. In a few cases, however, atypical modes of disposal (e.g., untreated FGD ponding, disposal in lined areas) were considered if they offered an opportunity to bracket potentially high and low impact conditions.

- In all cases, the data presented here in Section 3.0 is based on information available to the investigators in mid-1980 before site visits.

- The selection of candidate sites was not the final step in the site selection process. After EPA approval the candidate sites were examined further from two different viewpoints:

  - Additional data were obtained to confirm or deny the anticipated advantages of the candidate sites. Collection of this data required talking to representatives of the utilities, visiting the sites, studying soil survey data, and reviewing other available information on the disposal sites.

  - Obtaining utility cooperation was a key step in the further consideration of candidate sites.

Section 5.0 of this report describes the process by which the list of candidate and backup sites led to the final selection of sites for the program.

3.1 REGION A1: GULF COASTAL PLAIN REGION

3.1.1 Background

The Gulf Coastal Plain Region includes the eastern half of Texas, southern and western Alabama, southeastern Arkansas, all of Louisiana, Mississippi and Florida, and small portions of southeastern Oklahoma, southeastern Missouri, western Kentucky, western Tennessee, the southern tip of Illinois, and southwestern Georgia.

As of 1977, the region had 21 coal-fired (greater than 80% of power generated from coal) power plants with a total capacity of 19,722 Mw. Nineteen of these plants, with a capacity of 19,592 Mw, have individual capacities of greater than 200 Mw and are considered further in this section. Table 3.1.1 summarizes the baseline data for these 19 plants. These plants are generally located (a) along the Gulf Coast in Florida, Mississippi, and Alabama; (b) scattered throughout southeastern Texas; and (c) along the Tennessee and Mississippi Rivers in Tennessee, Kentucky, Illinois, and Missouri.

As of 1979, plant generating capacities ranged from a low of 218 Mw to a high of 2379 Mw. Twelve of the plants fell in the 900 to 1800 Mw range, while the other seven were between 200 and 600 Mw. Thirteen plants had start-up dates* of less than 15 years prior, while the remaining six had start-up dates ranging anywhere from 25 to 35 years prior. Of the five operational FGD systems in this region, four had been operating for under three years while the one at the Shawnee plant had been in existence for nearly eight years, but was no longer operating regularly.

This physiographic region and the prevailing climatic conditions are described in detail in Exhibit C. Average annual gross precipitation ranges from 127 to 165 cm (50 to 65 in.), while average net precipitation ranges from 25 to 50 cm (10 to 20 in.). Characteristic mild to hot ambient temperatures for this region range from about -15 to 41°C (5 to 105°F), while the average annual temperature is 16 to 18°C (60 to 65°F). Much of the region is flat, with similar geologic formations and deposits. The area is characterized by sandy, silty, clayey, coastal soils with some alluvium deposits. Frost penetration generally is less than 3 cm (1 in.) throughout most of this region except for the northward extension of the region along

---

*Date on which coal became the primary source of fuel.

Table 3.1.1

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN GULF COASTAL PLAIN REGION (A1) OF THE U.S.

Plant Name	Utility Name	Capacity (Mw)[b,e] Nameplate Generating	FGD Scrubbed	State	County	Start-up Date Plant[c,d]	FGD[e]	Waste Type[f]	Disposal Method[e,f]
Barry*	Alabama Power	1,770	--	AL	Mobile	2/54	--	Comb. Fly & Bottom	Pond(UL)
Greene*	Alabama Power	568	--	AL	Greene	5/65	--	Comb. Fly & Bottom	Pond(UL)
Tombigbee	Alabama Electric Coop.	585	358	AL	Washington	6/69	9/78	Fly Ash Bottom Ash FGD	? ? Pond(L)
Big Bend	Tampa Electric	1,336	--	FL	Hillsborough	10/70	--	NA	NA
Crist*	Gulf Power	1,229	--	FL	Escambia	7/59	--	Comb. Fly & Bottom	Pond(UL)
Smith*	Gulf Power	340	--	FL	Bay	6/65	--	Comb. Fly & Bottom	Pond(UL)
Mitchell*	Georgia Power	218	--	GA	Dougherty	11/48	--	Comb. Fly & Bottom	Pond(UL)
Wansley*	Georgia Power	951	--	GA	Coweta	1/76	--	Comb. Fly & Bottom	Pond(UL)
Joppa	Electric Energy	1,100	--	IL	Massac	-/53	--	NA	NA
Shawnee*	Tennessee Valley Authority	1,750	20	KY	McCracken	4/53	4/72	Comb. Fly & Bottom FGD	Pond(UL) ?
R.D. Morrow*	Southern Mississippi Electric	360	248	MS	Lamar	2/78	8/78	Fly Ash Fly/FGD Bottom Ash	Landfill(UL)/Sold Landfill(UL) Landfill(UL)
New Madrid	Associated Electric Coop.	1,200	--	MO	New Madrid	-/72	--	NA	NA
Allen*	Tennessee Valley Authority	990	--	TN	Shelby	1/65	--	Comb. Fly & Bottom	Pond(UL)
Johnsonville*	Tennessee Valley Authority	1,485	--	TN	Humphreys	10/51	--	Comb. Fly & Bottom	Pond(UL)
Big Brown*	Texas Power & Light	1,186	--	TX	Freestone	12/71	--	Fly Ash Bottom Ash	Landfill(CS) Pond(CS)
Deeley*	San Antonio Public Ser. Board	447	--	TX	Bexar	6/78	--	Fly Ash Bottom Ash	Landfill(CS,AL) Interim Pond(UL);Sold
Martin Lake*	Texas Power & Light	2,379	1,785	TX	Rusk	5/77	10/78	Fly Ash Bottom/FGD	Landfill(mine) Interim Pond(CS); Landfill(mine)
Monticello*	Texas Power & Light	1,186	800	TX	Titus	12/74	10/78	Fly Ash Bottom Ash FGD	Landfill(UL) Interim Pond(CS); Landfill(UL) Pond(?)
Welsh*	Southwestern Electric Power	512	--	TX	Titus	3/77	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL)

FOOTNOTES TO TABLES 3.1.1 - 3.9.1

[a] Coal-fired plants with $\geq 80\%$ of power generated from coal in 1977 and capacities ≥ 200 Mw with exceptions for plants employing an FGD system.

[b] National Coal Association, "Steam Electric Plant Factors (1978)."

[c] Federal Energy Administration, "Inventory of Power Plants in the United States, April, 1979."

[d] Original start-up date of plant's first coal-fired unit.

[e] PEDCo Environmental, Inc., "EPA Utility FGD Survey: April-June 1979," August, 1979.

[f] Versar, Inc., actual utility plant data survey sheets used in developing the report entitled "Selection of Representative Coal Ash and Coal Ash/FGD Waste Disposal Sites for Future Testing," August, 1979.

[g] <80% of power generated from coal but included in table since its wastes are landfilled along with the St. Clair and Trenton Channel plants.

[h] FGD is no longer operational at this plant.

[i] Nameplate generating capacity is <200 Mw but plant has an operational FGD system.

[j] <80% of power generated from coal in 1977 but plant has an operational FGD system.

*Plants on which we have the actual utility plant survey data sheets submitted to Versar, Inc. in the course of their study.

(AL)	Artificially Lined
(CS)	Clay Substrate
(L)	Lined (exact liner unknown)
(UL)	Unlined
(?)	Unknown
NA	Not available from Versar Report

the Mississippi River Valley where it increases to approximately 38 cm (15 in.) in western Kentucky.

3.1.2 Assessment of Disposal Operations

Disposal operations in this region are assessed from three viewpoints:

- categorization of disposal operations;
- assessment of disposal operations from an engineering/technological perspective, leading to a preliminary rating; and
- special comments, if any, on handling and transportation of FGC wastes.

3.1.2.1 Categorization of Disposal Operations

Table 3.1.2 presents data on disposal methods in Region A1.

The utility operations of the Gulf Coastal Plain typically employed one or more of two basic disposal practices for fly ash, bottom ash, and FGC waste:

- single-step pond disposal for combined fly and bottom ash and for FGD waste, and
- single-step landfill disposal for fly ash.

Fly and bottom ash disposal in unlined ponds was practiced at nine of the 16 plants in this region on which information was available. Single-step landfill disposal of fly ash was practiced at six of the plants. Five of the plants in this region (including Shawnee) employed FGD systems. A general overview of the major types of disposal practiced in this region is presented below.

Disposal of Combined Fly and Bottom Ash in Ponds

Nine plants in this region were known to rely exclusively on single-step pond disposal. These were the Barry and Greene plants of Alabama Power, Crist and Smith of Gulf Power, Mitchell and Wansley of Georgia Power, and the Shawnee, Allen, and Johnsonville plants of Tennessee Valley Authority. All nine plants reportedly disposed of their combined fly ash and bottom ash in unlined ponds. Based on available data, only one out of these nine plants, the Smith plant, had ponds almost completely free of extraneous pond influents. Several of the other plants had anywhere from 20 to 65% extraneous pond influents, primarily attributable to cooling tower blowdown and building sumps. Although the extraneous influents might complicate the

Table 3.1.2

MATRIX OF FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS

> 200 Mw IN THE GULF COASTAL PLAIN REGION (A1) OF THE UNITED STATES IN 1979[a]

	Number of Plants		
Type of Waste	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	-	6	-
Bottom ash only	2	1	2
Combined fly and bottom ash	9	-	-
FGD waste only	2	-	-
Mixed fly ash and FGD waste	-	1	-
Mixed bottom ash and FGD waste	-	-	1
Mixed fly ash and FGD waste (stabilized)	-	-	-
Mixed fly ash, bottom ash, and FGD waste	-	-	-

---

[a] Coal-fired plants (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal.

Source: Compiled by Arthur D. Little, Inc. based on Utility Plant Data Survey Sheets used in developing reference (1).

character of the pond, it appeared that the mixing of such wastes with fly and bottom ash was a somewhat typical utility practice, and therefore cannot be ignored.

Disposal of Fly Ash in Landfills

Six plants reportedly practiced the landfilling of fly ash. These were R.D. Morrow of Southern Mississippi Electric, Big Brown, Martin Lake, and Monticello of Texas Power & Light, Deeley of San Antonio Public Service Board, and Welsh of Southwestern Electric Power. However, only two of these six plants disposed solely of fly ash in their landfill. These were Big Brown and Deeley.

Disposal of Fly Ash, Bottom Ash, and FGD Waste in Ponds and Landfills

Of the plants listed in Table 3.1.1 on which the investigators had reported data, there were only four with reported operational FGD systems. These were Tombigbee, R.D. Morrow, Martin Lake, and Monticello. R.D. Morrow of Southern Mississippi ELectric practiced direct landfilling of FGD waste co-disposed with fly ash and landfilling of bottom ash after dewatering. At Tombigbee of Alabama Electric and Monticello of Texas Power & Light, ponding of FGD waste was practiced in contrast to the co-disposal practiced at R.D. Morrow. At Martin Lake, co-disposal of FGD waste with bottom ash to an interim pond, followed by a landfill was practiced. The Shawnee plant of TVA also employed an FGD system but it had been operating sporadically during 1979-1980. In addition, the plant was already participating in an on-going EPA research project. In view of these facts, this plant was not considered a suitable site.

3.1.2.2 Assessment of Disposal Operations

Table 3.1.3 presents the results of the disposal operation assessment rating for Region A1. The methodology employed in making this assessment is discussed in Section 2.6. The Barry, Greene, Tombigbee, Crist, Smith, Mitchell, Wansley, Big Brown, Deeley, Monticello, and Welsh plants appeared to warrant further evaluation from the disposal operation perspective. Three plants (R.D. Morrow, Allen, and Martin Lake) were eliminated from further consideration due to one of two factors: (1) the disposal site was less than two years old; or (2) the plant had sold more than 50% of its coal ash in the last one to two years.

3.1.2.3 Comments on Handling and Transportation of FGC Wastes

Except for the Martin Lake disposal operation (landfilling of ash and FGD wastes in mine vee notches) the handling and transportation of FGC wastes

Table 3.1.3

ASSESSMENT OF DISPOSAL OPERATIONS IN GULF COASTAL PLAIN REGION (A1) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Barry		1 1/2+	1/2+	0	2+	Extraneous pond influents are primarily due to building sumps.
Greene		1+	1/2+	0	1 1/2+	Extraneous pond influents are primarily due to building sumps.
Tombigbee		1 1/2+	1 1/2+	1/2+	3 1/2+	Ponding of FGD waste is practiced.
Big Bend		1 1/2+	NA	NA	NA	
Crist		1 1/2+	1/2+	0	2+	Extraneous pond influents are primarily due to cooling tower blowdown.
Smith		1+	1/2+	0	1 1/2+	
Mitchell		1 1/2+	1/2+	0	2+	Extraneous pond influents are classified as low volume water.
Wansley		1 1/2+	1/2+	1/2+	2 1/2+	Pond is 3 years old.
Joppa		1 1/2+	NA	NA	NA	
Shawnee		1 1/2+	1 1/2+	0	3+	FGD system was a test facility. FGD has been operating sporadically.
R.D. Morrow	X	1 1/2+	1 1/2+	1/2+	X	Landfill is < 2 years old. FGD has been operating sporadically.
New Madrid		1 1/2+	NA	NA	NA	
Allen	X	1 1/2+	1/2+	0	X	Plant employs cyclone-fired boiler. Sold majority of coal ash in 1978.
Johnsonville		1 1/2+	1/2+	0	2+	Portions of retired ash pond area are being used as a chemical disposal site.
Big Brown		1 1/2+	1/2+	1 1/2+	3 1/2+	
Deeley		1 1/2+	1/2+	1+	3+	Landfill is 2 1/2 years old. Landfill is lined with clay in one portion and PVC in another. Bottom ash pond is 2 1/2 years old.
Martin Lake	X	1 1/2+	1 1/2+	1+	X	FGD and bottom ash are co-disposed with fly ash in a landfill. Landfill is a mine. Sold majority of coal ash in 1978.
Monticello		1 1/2+	1 1/2+	1+	4+	FGD waste is calcium sulfite rich.
Welsh		1 1/2+	1/2+	1+	3+	Pond is 3 years old. Extraneous pond influents are classified as low volume water.

---

[a] Assessment rating system explained in Section 2.6.

followed conventional practices. Similarly, the majority of plants wet sluiced both fly and bottom ash (see Table 2.4.4).

3.1.3 Geotechnical and Hydrogeologic Considerations

Table 3.1.4 presents an evaluation of geotechnical and hydrogeologic considerations and subsequent ratings for the sites in Region A1 taking into account information available to the investigators as of April 21, 1980. The methodology employed in making this assessment was presented in Section 2.7.

3.1.4 Other Site Selection Considerations

3.1.4.1 Discussion

The climate in the Gulf Coastal Plain Region is not characterized by extreme temperature fluctuations. None of the 19 plants in this region is located in an area with greater than 7000 annual degree days. This is the wettest region in the East; thirteen of the 19 plants experience precipitation extremes of greater than 120 cm per year (gross). All of the locations in this region have greater than 150 frost-free days per year; so that opportunities to study freeze/thaw effects are minimal. The regional setting for five of the plants was believed to be characterized by a combination of excessive precipitation and pervious coastal soils, promoting potential contaminant migration. Groundwater utilization was reported critical by the Second National Water Assessment (21) in the area of two of the sites, while in one area the potential to deplete 70% of the surface water supply in a dry year was reported.

A brief description of the plants with some pertinent information is presented in Exhibit D.

3.1.4.2 Ratings

Table 3.1.5 presents the results of the other site selection ratings for Region A1. The methodology for the rating is discussed in Section 2.8, and the individual site information is presented in Exhibit D.

3.1.5 Candidate and Back-Up Sites

In Region A1 the targeted number of sites were:

- candidate sites: one or two,
- back-up sites: one or two.

Given the predominance of combined fly and bottom ash ponding as a mode of disposal in this region, it was clear that the primary candidate and back-up sites should probably be those that employ this type of disposal. Consequently, efforts were focused on the most suitable candidates for combined fly and bottom ash ponding. In addition, since there will likely be more future plants in this region with FGD systems (see Table

Table 3.1.4

GEOTECHNICAL/HYDROGEOLOGIC RATING OF SITES - REGION A1

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Barry - Alabama Power Co./ Mobile County, AL, 21°-0'-0" N, 88°-0'-0" W	C	15'-20' of marine CL-ML and peat over fine sand; 67" avg. annual precip. (gross), -5" net; avg. annual temp. = 70°F, range 25° to 105°; frost penetration = <1" max; Quaternary marine sediments; sandy, silty, clayey soils typically.	The geotechnical data available indicate the presence of clay and silt layers, mixed with peat, over fine sand. The seasonal precipitation at the site is adequate to produce infiltration and leachate, but groundwater flow in the clay, silt and peat would be extremely complex and clay and peat layers could change leachate chemistry drastically.
Greene - Alabama Power Co./ Greene County, AL, 32°-36'-15" N, 87°-47'-30" W	C	0'-22' clayey silt/sandy silt, 22'-35' clayey sand, below 35' dense chalk; 50.5" avg. annual precip. (gross), approx. 10" net; frost penetration = 5" max.; Alabama River watershed; avg. annual temp. = 60°F, range 10° to 100°; Cretaceous marine deposits, with deep overlying residual soils.	The seasonal precipitation and lack of serious frost effects should give adequate infiltration to produce leachate and significant groundwater movement at the site. However, the silt and clayey sand layers would tend to slow such flow and make groundwater sampling and monitoring difficult. The presence of underlying chalk could alter groundwater flow in an erratic way by flow in solution channels and could chemically alter leachate character.
Tombigbee - Alabama Electric/ Washington County, AL, 31°-30' N, 88°-0' W	A-	Alluvial stream (Quaternary) deposits; shales, sandstones; 55"-60" avg. annual precip. (gross), 5"-10" net; avg. annual temp. = 65°F, range 20° to 100°; frost penetration negligible. Water table?	High seasonal precipitation with negligible frost action should support local groundwater flow. Alluvial soils overlying shale bedrock should facilitate groundwater monitoring and analysis. Site-specific data are needed to confirm preliminary rating.
Big Bend		Inadequate data for geotechnical evaluation.	
Crist - Gulf Power/Escambia County, FL, 30°-33'-57" N, 87°-13'-29.5" W (Pensacola)	B+	60" avg. annual precip. (gross), -4" net; avg. annual temp. = 70°F, range 25° to 105°; frost penetration negligible; Quaternary marine sediments, unconsolidated; sandy, silty coastal soils, a more pervious soil.	The heavy seasonal precipitation and negligible frost penetration should provide ample infiltration to support local groundwater flow. The thick sandy coastal soils at the site should facilitate analysis of the groundwater flow system, but the possibility of rapid flow with consequent dilution could hamper assessment of leaching activity.
Smith - Gulf Power Co./Bay County, FL (Panama City)	B+	Generally same data as for Crist. Need more soil data. Quaternary shore deposits. Very high water table?	Precipitation and lack of serious frost action should provide ample infiltration to support local groundwater flow. The soils beneath the site probably are sandy coastal soils to great depth, but data are scant. Sandy soils to great depth could provide easily understood flow media, but a very high water table and/or rapid flow could complicate analysis.
Mitchell - Georgia Power/ Dougherty County, GA		Sedimentary deposits. Tertiary, Cretaceous Quaternary. No soil data now available. In the Coastal Plain.	Inadequate data for geotechnical evaluation.

Table 3.1.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Wansley - Georgia Power/ Coweta County, GA (20 miles SW of Atlanta)		Igneous and metamorphic rock units; no soil data.	Inadequate data for geotechnical evaluation.
Joppa - Electric Energy/ Massac County, IL	A-	Well-sorted glacial sands and gravels with recent alluvium of Ohio River. Bedrock is sandstones and shales of Cretaceous age (at 90' to 100'). 45" avg. annual precip., -6" net; avg. annual temp. = 55°F, range 0° to 100°; frost penetration equals 15" avg.	The subsoils beneath this site consist of well-graded sands and gravels overlain by silty sands. Should provide ideal medium for monitoring activities. Only slight frost penetration should not impede infiltration, but local recharge to groundwater flow system may be limited by net evaporation and seasonal precipitation at the site.
Shawnee - TVA/McCracken County, KY, 37°-09'-54" N, 88"-47'-46" W	B-	Glacial sand and gravel under a cover of loess (10'-15'); Mississippian LS at depth; water table above pond bottom; 48" avg. annual precip. (gross), 0"-5" net; avg. annual temp. = 55°F, range 5° to 100°; frost penetration = 15" avg.	Net precipitation is ample at this site to support local infiltration and abundant groundwater flow. Frost action should not seriously impede infiltration. The presence of a water table above the bottom of the disposal pond at the site may significantly complicate groundwater flow conditions and make analysis difficult. The subsoils at the site are pervious and should provide a good medium for flow measurements.
R. D. Morrow - Southern Miss. Elec./Lamar County, MS (Pascagoula River)	B-	Landfill is being done in alluvium over a deep marine silty clay (Hattiesburg Formation). Alluvium consists of 10' to 25' of clay and silt layers, over sand-gravel materials. Coefficient of permeability in upper clayey alluvium was reported as 6 x 10^{-6} cm/sec to 10^{-7} cm/sec. [Citronelle and Pascagoula formations? Shales, sandstones, some conglomerates with overlying alluvium. 55"-60" avg. annual precip. (gross), 5"-10" net; avg. annual temp. = 65°F, range 20° to 100°; frost penetration negligible. Water table?]	Heavy seasonal precipitation and negligible frost action should support plentiful local groundwater flow. The subsoils of alluvium over silty clay favor monitoring and analysis except where clayey layers of alluvium are present.
New Madrid		Inadequate data for geotechnical evaluation.	
Allen - TVA/Shelby County, TN, 35°-04'-23" N, 90°-07'-58" W (Memphis, on Mississippi River)	B-	51" avg. annual precip. (gross), 10" net; avg. annual temp. = 60°F, range 5° to 100°; Quaternary deposits consisting of loess, overlying Tertiary sandstone, and glacial and modern alluvium near Mississippi River. Silty residual soils developed from loess and sandy-clayey soils on alluvium. Water table at 23'; pond bottom at 25'. Frost penetration ~10" avg.	Ample precipitation with limited short-term frost action should provide infiltration ample to support local groundwater flow. Silty surface soils over alluvium over sandstone bedrock could constitute conditions difficult to interpret (leakage through sandstone?). Water table above pond bottom complicates flow situation.
Johnsonville Steam Plant - TVA/Humphreys County, TN, 36°-01'-28" N, 87°-59'-34" W (on Kentucky Lake)	B+	51° avg. annual precip. (gross), 13" net; avg. annual temp. = 58°F, range 0° to 100°; frost penetration = 20" per winter season. Quaternary alluvium overlying Mississippian shales and sandstones of Borden Formation.	Ample net precipitation and only moderate frost penetration should guarantee local infiltration and recharge to the groundwater system at this site. The alluvial soils underlying the plant site should provide a good medium for flow monitoring, although the location of the plant adjacent to Kentucky Lake may make flow conditions very difficult to monitor. Lake levels may govern flow conditions in an erratic manner and it may be difficult, if not impossible, to interpret study results.

Table 3.1.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Big Brown - Texas Utilties/ Freestone County, TX 31°-49'-0" N, 96°-2'-30" W (on Trinity River, drainage Big Brown Cr.?; E. Fort Worth)	B	1' of "select clay" below bottom ash pond. 8-yr old fly ash landfill lined with "selected clays"; 44" avg. annual precip. (gross), -26" net; Cretaceous marine sediments under Tertiary marine sediments (?); sandy, silty, clayey coastal soils, some alluvium (?); avg. annual temp. = 65°F, range 25° to 105°F; frost penetration = 2".	The net evaporation at this site may limit local groundwater flow unless flow is supported from deep sources. The sandy and silty soils with possibly some stream alluvium could provide understandable conditions for flow analysis, while the effectiveness of a clay liner also could be evaluated.
Deely - Bexar Co., /City Public Service Board of San Antonio, TX 29°-18'25" N, 98°-19'-03" W (near Lake Braunig)	B-	Bottom ash ponded then used. Fly ash ponded. 29°-19'-06" N, 98°-18'-59" W; fly ash pond (landfill)	Average gross annual precipitation = 30", net precipitation average = -35.4". Average annual temperature = 70°F; range = 20°F to 100°F. Frost penetration during winter season = 1" average. Tertiary (Eocene) Claiborne formation of sandstones, conglomerates and shales. Bottom ash pond is 10' deep; about 7' to water table. Pond is only 2 1/2 years old. 100% bottom ash. No monitoring wells. Fly ash disposal area is only 2 1/2 years old. Landfill 20' thick, 16' to water table. Site is composed on two compartments, one lined with clay, the other lined with PVC. Four monitor wells. Site underlain to 36' by sand with silt and clay lenses.
Martin Lake - Texas Utilities/ Rusk County, TX, 32°-15'-50" N, 94°-34'-33" W (SW of Shreveport, LA; Sabine River drainage?)	B-	1' of "select clay" below bottom ash pond. Fly ash, bottom ash and FGD waste mixed, then landfilled. Clays, sandy clays mixed with silty sands and clayey sands to depths of 11'-28'; low permeability for sands (k 10^{-6} cm/sec). Underlying soils to 70' are clays, sandy clays with lenses of silty sand, sandy silt and lignite. 48" avg. annual precip. (gross), -22" net; avg. annual temp. = 65°F, range 25° to 105°; frost penetration = 2" max. Same soil as Big Brown, Tertiary marine deposits.	Net evaporation at this site may limit infiltration and local groundwater flow, while the clay layers and sands of low permeability at the site could retard and distort flow, making analysis difficult. Site provides the opportunity to evaluate the efficacy of a clay liner.
Monticello - Texas Utilities/ Titus County, TX, 33°-5'-30" N, 95°-2'-30" W (80-100 miles east of Dallas)	B-	45" avg. annual precip. (gross), -23" net; 12" "select clay" liner for bottom ash pond. Soils below landfill for bottom ash, fly ash and FGD wastes are clays interspersed with clayey and silty sands; avg. annual temp. = 65°F, range 10° to 100°; frost penetration = 2" max; Cretaceous marine sedimentaries; clayey, sandy, silty coastal soils.	Net evaporation at this site may limit infiltration and local groundwater flow, while the clay layers and clayey, silty sand layers may cause selective flow in the sandy layers (perhaps a situation quite difficult to analyze). Opportunity to evaluate efficacy of clay liner.
Welsh - Southwestern Elec. Power Co./Titus County, TX		Inadequate data for geotechnical evaluation.	

Table 3.1.5

OTHER SITE SELECTION RATINGS FOR DISPOSAL OPERATIONS IN THE GULF COASTAL PLAIN REGION (REGION A-1)

REGIONAL/GENERIC FACTORS SITE-SPECIFIC FACTORS

Plant & Utility	Total Rating (+ and -)	Climate			Contaminant Migration Factor (Climate and Soils) (+)	Water Use		Setting		Mitigative Controls			Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
		Temp. >7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)		G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)			
Barry, Al. Power	BA/FA Pond 3+	0	+	0	0	+	0	+	NA	0	0	0	+	NA	-
Greene, Al. Power	BA/FA Pond 1+	0	+	0	0	0	0	+	NA	0	0	0	0	NA	-
Tombigbee, Al. Elec. Coop	FGD Pond (L) 5+	0	+	0	+	NA	0	NA	NA	0	+	NA	+	+	NA
Big Bend, Tampa Elec.	NA 3+	0	+	0	+	0	0	NA	NA	NA	NA	NA	+	NA	NA
Crist, Gulf Power	BA/FA Pond 2+	0	+	0	+	0	0	NA	NA	0	0	0	+	NA	-
Smith, Gulf Power	BA/FA Pond 3+	0	+	0	+	0	0	+	NA	0	0	0	NA	NA	NA
Mitchell, Ga. Power	BA/FA Pond 3+	0	+	0	+	0	0	NA	NA	0	0	0	+	+	-
Wansley, Ga. Power	BA/FA Pond 2+	0	+	0	0	0	0	NA	NA	0	0	0	NA	+	NA
Joppa, Elec. Energy	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Shawnee, TVA	Var. Ponds 1+	0	+	0	0	0	0	NA	NA	0	0	0	+	+	—
R.D. Morrow, S.Ms. Elec.	FA/BA/ FGD Fill 3+	0	+	0	0	0	0	-	0	+	0	+	NA	+	NA
New Madrid Ass. El. Coop	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA

Table 3.1.5 (Continued)

Plant & Utility	Total Rating (+ and -)	REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate			Contaminant Migration Factor (Climate and Soils) (+)	Water Use		Setting		Mitigative Controls			Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
		Temp. >7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)		G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)			
Allen, TVA	BA/FA Pond 1+	0	+	0	0	NA	0	NA	NA	0	0	0	+	0	-
Johnsonville, TVA	BA/FA Pond *	0	+	0	0	0	0	-	+	0	0	0	+	0	--
Big Brown Texas P&L	FA Fill 4+	0	0	0	0	0	+	NA	NA	+	NA	0	+	+	NA
	BA Pond 4+	0	0	0	0	0	+	+	NA	0	NA	0	+	+	NA
Deeley San Antonio Pub. Ser. Board	FA Fill 5+	0	0	0	0	0	0	NA	NA	+	+	0	++	+	NA
	BA Pond 2+	0	0	0	0	0	0	NA	NA	0	0	NA	NA	++	NA
Martin Lake Texas P&L	Com. Fill 3+	0	+	0	0	0	0	-	NA	+	NA	0	+	++	-
	FGD Pond 2+	0	+	0	0	0	0	NA	NA	0	NA	0	NA	+	NA
Monticello Texas P&L	Com. Fill 2+	0	0	0	0	0	0	NA	NA	+	0	NA	+	+	-
	Bot. Ash 2+	0	0	0	0	0	0	+	NA	0	NA	NA	NA	+	NA
	FGD Pond 1+	0	0	0	0	0	0	NA	NA	0	NA	NA	NA	+	NA
Welsh South. Elec. Power	Com. Fill 1+	0	0	0	0	0	0	NA	NA	+	0	0	+	NA	-
	Bot. Ash 1-	0	0	0	0	0	0	NA	NA	0	0	0	NA	NA	-

Key:
NA = Information not available
0 = Not applicable
* = Sum of + and - is zero
ppt. = Precipitation
G.W. = Groundwater
S.W. = Surface water

Note: Rating methodology is described in Section 2.8; information on plants is summarized in Exhibit D.

2.4.7), emphasis was also placed on selecting some of the few plants practicing the disposal of FGD waste. Ponding of FGD waste alone is not a typical method of disposal in this region, but it does define one potentially important type of environmental impact setting. One site in this region employs this practice as potentially mitigated by a pond liner.

The nominated candidate and back-up sites are shown below:

Waste Type/Disposal Method	Candidate Sites	Back-Up Sites
Coal Ash Only		
Combined Fly & Bottom/Pond (UL)	Smith	---
Fly Ash/Landfill (CS) Bottom Ash/Pond (CS)	---	Big Brown
Coal Ash & FGD		
Fly Ash/ ? Bottom Ash/ ? FGD/Pond (L)	Tombigbee	---

Table 3.1.6 provides an overview on these sites' characteristics. A brief description of these sites and some others of interest follows.

Smith, Gulf Power

Smith of Gulf Power was designated a candidate site. It is a small (340-Mw) relatively new (14-year-old as of 1979) plant practicing combined fly and bottom ash disposal in an unlined pond. It appears to have favorable site characteristics; the plant appears to be located on sandy silty soil which is considerably more porous than the sandy clayey soils also found in Region A1. This plant has a very small reported flow of external influents into the ash ponds (1%). The plant does not have any existing monitoring wells. It is located on the coast and offers a typical combination of mode of disposal and soil characteristics for this region.

Tombigbee, Alabama Electric

Tombigbee of Alabama Electric was designated a candidate site since it affords the opportunity to evaluate the lined ponding of FGD waste. Because of insufficient data, the mode of ash disposal at Tombigbee was not known for certain, but it was believed to be ponding fly and bottom ash together. Unless further data could be obtained, very little could be said of the hydrogeology at Tombigbee, except that it was believed quite possible that favorable alluvium deposits might exist due to the plant's location near the Tombigbee River.

Table 3.1.6

RECOMMENDED CANDIDATE AND BACK-UP SITES - GULF COASTAL PLAIN - REGION A1

	Candidate	Description	Assessment of Disposal Operations	Geotechnical/Hydrogeologic Considerations	Other Factors
1	Smith Plant Gulf Power Bay County, FL	340-Mw plant started up in 1965. Combined fly and bottom ash disposal in ponds.	Important smaller plant with typical disposal practice in region. 1 1/2+	Sandy soils could provide good understanding of flow regime. High water table and rapid flow present complications. B+	Coastal location, almost no miscellaneous influents. Typical disposal practice. 3+
2	Tombigbee Plant Alabama Electric Coop Washington County, AL	585-Mw plant started up in 1969 (FGD in 1978). Fly and bottom ash disposal unknown. FGD waste disposal in ponds.	FGD ponding in lined ponds potentially important for future assessment efforts. 3 1/2+	Alluvial soil over bedrock facilitates monitoring. High seasonal precipitation with negligible frost action. A-	Important disposal mode in coastal region and control practices. 5+
	Back-up				
3	Big Brown Texas Power and Light Freestone County, TX	1186-Mw plant started up in 1977. Fly ash disposal in a landfill; bottom ash to a pond.	Landfill disposal has future potential in region. Recycle of bottom ash pond effluent practiced. 3 1/2+	Net evaporation may limit groundwater flow. Sandy and silty soils. B	Surface water utilization critical in area. 100% fly ash fill. 4+

Big Brown, Texas Power & Light

Big Brown of Texas Power & Light was designated as a back-up site. The plant's reported disposal practice included the ponding of bottom ash with virtually no extraneous pond influents and the landfilling of fly ash, exclusively. Both sites are underlain by a foot of clay. It is located in a region reported critical for surface water utilization. This plant had the potential of being a back-up for a western region plant such as Dave Johnston and/or the Interior Lowland region plant - Powerton, which both landfill fly ash. In addition, Big Brown could also be a potential back-up for several plants which also practiced the ponding of bottom ash, such as Sherburne County and Clifty Creek.

R.D. Morrow, Southern Mississippi Electric

R.D. Morrow plant of Southern Mississippi Electric is a plant which in some respects rated highly and was of particular interest because it offered an opportunity to evaluate the co-disposal of fly ash and FGD sludge in a landfill. However, closer evaluations indicated that this plant had not had steady FGD system operation nor had the landfill been in operation for the required minimum of two years. Hence, it was eliminated from further consideration.

Some other sites of potential interest in this region (not in any special order) were:

- Monticello, Texas Power & Light
- Deeley, San Antonio Public Service

3.2 REGION A2: PIEDMONT AND COASTAL PLAIN REGION

3.2.1 Background

The Piedmont and Coastal Plain region includes most of Georgia, essentially all of South Carolina, most of North Carolina (except for the westernmost portions which are in Region B), the eastern portions of Virginia and Maryland, Delaware, and a small portion of Pennsylvania.

As of 1977, the region had 33 coal-fired (greater than 80% of power generated from coal) power plants with a total of 21,849 Mw.* Twenty-eight of these plants, with a capacity of 21,236 Mw, had individual capacities of greater than 200 Mw and are considered further in this section. Table 3.2.1 summarizes the baseline data for these 28 plants. Plant locations are generally scattered throughout the region.

Plant generating capacities ranged from a low of 206 Mw to a high of 2160 Mw. Twenty-one of the plants fell in the 200 to 900 Mw range, while the other seven ranged from 1100 Mw to 2200 Mw. In 1980, five of the plants had start-up dates** of less than 15 years prior; seventeen plants had start-up dates of 15 to 30 years prior; and six plants had start-ups of greater than 30 years prior. Both of the operational FGD systems in this region were started up within the last three to five years.

---

*Includes plants that were <80% coal-fired in 1977 because they employ FGD systems.

**Date on which coal became the primary source of fuel.

Table 3.2.1

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN PIEDMONT & COASTAL PLAIN REGION (A2) OF THE U.S.

Plant Name	Utility Name	Capacity (Mw)[b,e]		State	County	Start-up Date		Waste Type[f]	Disposal Method[e,f]
		Nameplate Generating	FGD Scrubbed			Plant[c,d]	FGD[e]		
Indian River*	Delmarva Power & Light	340	--	DE	Sussex	-/57	--	Comb. Fly & Bottom	Pond(UL)
Harlee Branch*	Georgia Power	1,746	--	GA	Putnam	6/65	--	Comb. Fly & Bottom	Pond(UL)
McDonough*	Georgia Power	598	--	GA	Cobb	8/63	--	Fly Ash	Sold
								Comb. Fly & Bottom	Pond(UL)
Yates*	Georgia Power	1,487	--	GA	Coweta	9/50	--	Comb. Fly & Bottom	Pond(UL)
Dickerson*	Potomac Electric Power	586	--	MD	Montgomery	6/59	--	Fly Ash (Scrubber)	Interim Pond(UL); Landfill(off-site)
								Fly Ash	Landfill(off-site)
								Bottom Ash	Interim Pond(UL); Landfill(off-site)
Allen*	Duke Power	1,155	--	NC	Gaston	-/57	--	Comb. Fly & Bottom	Pond(UL)
Belews Creek*	Duke Power	2,160	--	NC	Stokes	5/74	--	Comb. Fly & Bottom	Pond(UL)
Buck*	Duke Power	440	--	NC	Rowan	-/26	--	Comb. Fly & Bottom	Pond(UL)
Cape Fear*	Carolina Power & Light	390	--	NC	Chatham	8/42	--	Comb. Fly & Bottom	Pond(UL)
Cliffside*	Duke Power	781	--	NC	Cleveland	-/40	--	Comb. Fly & Bottom	Pond(UL)
Dan River*	Duke Power	290	--	NC	Rockingham	-/49	--	Comb. Fly & Bottom	Pond(UL)
Lee*	Carolina Power & Light	402	--	NC	Wayne	5/51	--	Comb. Fly & Bottom	Pond(UL)
Marshall*	Duke Power	2,000	--	NC	Catawba	-/65	--	Comb. Fly & Bottom	Pond(UL)
Riverbend*	Duke Power	466	--	NC	Gaston	-/29	--	Comb. Fly & Bottom	Pond(UL)
Roxboro*	Carolina Power & Light	1,813	--	NC	Person	5/66	--	Comb. Fly & Bottom	Pond(UL)
Sutton*	Carolina Power & Light	671	--	NC	New Hanover	8/54	--	Comb. Fly & Bottom	Pond(UL)
Eddystone[j]	Philadelphia Electric	1,489	120	PA	Delaware	2/60	9/75	NA	NA
Titus*	Metropolitan Edison	225	--	PA	Berks	-/51	--	Fly Ash	Landfill(UL)
								Bottom Ash	Hydrobin; Landfill(UL)
Canadys	S.Carolina Electric & Gas	489	--	SC	Colleton	4/62	--	NA	NA
Jefferies	S.Carolina Public Ser. Auth.	445	--	SC	Berkley	-/69	--	NA	NA
Lee*	Duke Power	345	--	SC	Anderson	-/51	--	Comb. Fly & Bottom	Pond(UL)
McMeekin	S.Carolina Electric & Gas	293	--	SC	Lexington	7/58	--	NA	NA
Robinson*	Carolina Power & Light	206	--	SC	Darlington	5/60	--	Comb. Fly & Bottom	Pond(UL)
Urquhart	S.Carolina Electric & Gas	250	--	SC	Aiken	12/53	--	NA	NA
Wateree	S.Carolina Electric & Gas	771	--	SC	Richland	9/70	--	NA	NA
Winyah	S.Carolina Public Ser. Auth.	630	140	SC	Georgetown	5/75	7/77	FGD	Pond(UL)
								Fly Ash	?
								Bottom Ash	?
Bremo Bluff*	Virginia Electric & Power	254	--	VA	Fluvanna	6/50	--	Comb. Fly & Bottom	Pond(UL)
Potomac River*	Potomac Electric Power	514	--	VA	City of Alex.	10/49	--	Comb. Fly & Bottom	Landfill(off-site)

Footnotes follow Table 3.1.1.

This physiographic region and the prevailing climatic conditions are described in detail in Exhibit C. Average annual temperatures in this region vary from approximately 18°C (64°F) in the southernmost portions to approximately 13°C (55°F) in the northern portion, near the Chesapeake Bay area. Annual average precipitation varies from approximately 115 cm (45 in.) in the northern portion of the region to about 140 cm (55 in.) in the southern portion. Average maximum temperatures throughout the region are approximately 38°C (100°F), and minimum temperatures generally increase from approximately -12°C (10°F) in the northern portion of the region, near Chesapeake Bay, to approximately -7°C (20°F) in Georgia. Frost penetration increases from approximately 3 cm (1 in.) in southern Georgia to approximately 46 cm (18 in.) in the extreme northern portion.

3.2.2 Assessment of Disposal Operations

3.2.2.1 Categorization of Disposal Operations

Table 3.2.2 presents summary data on disposal methods in Region A2. The utility operations of the Piedmont and Coastal Plain region typically employ one basic disposal practice for fly ash, bottom ash, and FGD waste:

- single-step pond disposal for combined fly and bottom ash; and
- single-step pond disposal for FGD waste. (Employment of FGD systems was not prevalent in this area.)

A general overview of the major types of disposal practiced in this region is presented below.

Disposal of Combined Fly and Bottom Ash in Ponds

There were 18 plants in this region on which the investigators had reported data (see Table 3.2.1) known to rely exclusively on single-step pond disposal of combined fly and bottom ash. An evaluation of the data indicates that most of the ponds in this region received up to 30 of their influent drainage in the form of coal-pile runoff and other external influents. Coal-pile runoff was originally assumed to be outside the scope of this project. The presence of coal-pile runoff in a pond is likely to lead to confounding contaminants and pose some difficulty in assessing groundwater or non-point surface water impacts at all the sites. This could only be avoided by including coal-pile runoff in the monitoring effort. After discussions with

Table 3.2.2

MATRIX OF FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS $>$ 200 Mw IN THE PIEDMONT AND COASTAL PLAIN REGION (A2) OF THE UNITED STATES[a]

	Number of Plants		
Type of Waste	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	-	2	1
Bottom ash only	-	1	1
Combined fly and bottom ash	18	1	-
FGD waste only	1	-	-
Mixed fly ash and FGD waste	-	-	-
Mixed bottom ash and FGD waste	-	-	-
Mixed fly ash and FGD waste (stabilized)	-	-	-
Mixed fly ash, bottom ash, and FGD waste	-	-	-

---

[a] Coal-fired plants (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal

Source: Compiled by Arthur D. Little, Inc. based on Utility Plant Data Survey Sheets used in developing the reference (1).

the EPA Project Officer, it has been decided to include sites that dispose of coal-pile runoff in the ponds, and additional funding for monitoring such complex sites was assumed in the site selection process.

Disposal of FGD Wastes in Ponds

The Winyah Plant (South Carolina Public Service Authority) appeared, based on available data, to be the only unlined, unstabilized FGD ponding operation in this high-precipitation sandy Coastal Plain area. It was believed that fly and bottom ash were ponded together in a separate pond; however, there was insufficient data to know for certain. This site may provide an excellent representation of one regional climatic/soils extreme for future assessment efforts of FGD waste disposal.

3.2.2.2 Assessment of Disposal Operations

Table 3.2.3 presents the results of the disposal operation assessment rating for Region A2. The methodology employed in making this assessment is discussed in Section 2.6. As in Region A1, several plants (Harlee Branch, Yates, Allen, Belews Creek, Cape Fear, Cliffside, Lee, Marshall, Roxboro, Sutton, Winyah, and Bremo Bluff) warranted further evaluation based on this rating alone. The McDonough plant was eliminated from further study due to the fact that the majority of its ash had been sold in recent years. The hydrogeologic and other factor ratings of these plants provided the discrimination necessary for selection of the candidate and back-up sites.

3.2.2.3 Comments on Handling and Transportation of FGC Wastes

Ponding is the dominant practice in this region. Consequently, most plants wet sluiced both fly ash and bottom ash (see Table 2.4.4). Conventional handling of slurries is typical; most, if not all, impoundments are onsite and the design follows conventional practice. Although ponding of FGD wastes is practiced in this region, it is not typical nor does it have strong future potential for FGD wastes. However, unlined ponding of FGD wastes in the wet coastal zone offered a potential study opportunity, as discussed below.

3.2.3 Geotechnical and Hydrogeologic Considerations

Table 3.2.4 presents an evaluation of geotechnical and hydrogeologic considerations and subsequent ratings for the sites in Region A2. The methodology employed in making this assessment is presented in Section 2.7. Allen, Sutton, and Winyah appear to have desirable hydrogeologic and geotechnical conditions. Soil data availability from the VERSAR report(1) is also reported in Table 3.2.4.

Table 3.2.3

ASSESSMENT OF DISPOSAL OPERATIONS IN GULF COASTAL PLAIN REGION (A2) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Indian River		1+	1+	0	2+	Ash pond operation will terminate to go to landfill disposal. Will employ a closed-loop ash handling system.
Harlee Branch		1 1/2+	1+	0	2 1/2+	Extraneous pond influents are classified as low volume water.
McDonough	X	1+	1+	0	X	Extraneous pond influent is classified as low volume water. Sold majority of fly ash in 1977.
Yates		1 1/2+	1+	0	2 1/2+	Extraneous pond influent is classified as low volume water.
Dickerson		1 1/2+	0	1/2+	2+	Employs wet particulate scrubber. Ash ponding has been terminated. Ash is now dewatered and landfilled off-site.
Allen		1 1/2+	1+	0	2 1/2+	Extraneous pond influent is primarily coal pile run-off.
Belews Creek		1 1/2+	1+	0	2 1/2+	Extraneous pond influent is primarily coal pile run-off.
Buck		1+	1+	0	2+	Extraneous pond influent is primarily coal pile run-off.
Cape Fear		1 1/2+	1+	0	2 1/2+	
Cliffside		1 1/2+	1+	0	2 1/2+	Extraneous pond influents are primarily coal pile and surface water run-off.
Dan River		1+	1+	0	2+	Extraneous pond influents are primarily coal pile and surface water run-off.
Lee		1 1/2+	1+	0	2 1/2+	
Marshall		1 1/2+	1+	0	2 1/2+	Extraneous pond influents are primarily coal pile and surface water run-off.
Riverbend		0	1+	0	1+	Extraneous pond influents are primarily coal pile and surface water run-off.
Roxboro		1 1/2+	1+	0	2 1/2+	
Sutton		1 1/2+	1+	0	2 1/2+	
Eddystone		1 1/2+	1+	NA	NA	Plant was < 80% coal-fired in 1977. FGD is a recovery process.
Titus		1+	0	1/2+	1 1/2+	Landfill has just about reached its design life of 30 years.
Canadys		1 1/2+	NA	NA	NA	
Jefferies		1 1/2+	NA	NA	NA	
Lee		0	1+	0	1+	Extraneous pond influents are primarily coal pile and surface water run-off.
McMeekin		0	NA	NA	NA	
Robinson		1+	1+	0	2+	
Urquhart		1/2+	NA	NA	NA	
Wateree		1 1/2+	NA	NA	NA	
Winyah		1 1/2+	2+	NA	3 1/2+	Ponding of FGD waste is practiced.
Bremo Bluff		1 1/2+	1+	0	2 1/2+	Extraneous pond influents include air preheater and boiler cleaning wastes. Pond may be underlain with clay.
Potomac River		1+	0	1/2+	1 1/2+	Landfill is off-site. Both fly and bottom ash are handled dry.

---

[a] Assessment rating system explained in Section 2.6.

Table 3.2.4

GEOTECHNICAL/HYDROGEOLOGIC RATING OF SITES - REGION A2

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Indian River - Delmarva Power and Light/Sussex County, DE (FA/BA pond)	C	46" avg. annual precip. (gross), 10" net; avg. annual temp. = 55°F, range 0° to 95°; frost penetration = 18" avg. per winter season. Area underlain by Quaternary shore deposits, sandstones, conglomerates and unconsolidated sediments. Pond is 10' deep; water table at 2'. 90% FA. Pond use is being terminated.	Only moderate frost penetration and high precipitation create ample local groundwater flow. Very high water table above pond bottom, in mixed shore deposits, creates very complex flow situation; very difficult to monitor and analyze.
Harlee Branch - Georgia Power/Putnam County, GA, 40-50 miles SE of Atlanta, 10-20 miles NW of Fall Line (drainage from sumps and drains, 30%;)	B-	Igneous bedrock mixed with some metamorphic rocks	Precipitation is sufficient to support local groundwater flow and frost action is not sufficient to significantly restrict infiltration. However, igneous bedrock units occurring among metamorphosed units may complicate flow pattern and analysis. More data on subsoils are needed.
McDonough - Georgia Power/Cobb County, GA (Atlanta) 33°-49'-20" N, 84°-28'-30" W (BA sluiced to pond; 45% ash sold; FA given to contractor)	C	48.6" avg. annual precip. (gross), 6" net; avg. annual temp. = 60°F, range 5° to 100°; frost penetration = 10" avg. per winter season. Pond is 90' deep. Residual soil underlain by very complex geology -- metamorphics of uncertain age. Granite gneisses, mica schists, with mafic gneisses.	Net precipitation with only very shallow frost penetration should create ample infiltration and local groundwater flow. Very deep pond in irregular residual soils developed from very complex sequence of metamorphic rock units creates a very complex flow system; very difficult to evaluate.
Yates - Georgia Power/Coweta County, GA, 20 miles SW of Atlanta, very near Chattahoochee River (34% other wastes inflow)	C+	Igneous and metamorphic bedrock units; possibly thin river alluvium also.	Only moderate frost action, with ample net precipitation should provide infiltration sufficient to support local groundwater flow. Igneous and metamorphic rock units below residual soils may create a very complex flow system although river alluvium may provide easily understood flow channel.
Dickerson - Potomac Electric Power/Montgomery County, MD (Dickerson), 39°-12'-30" N, 77°-28'-10" W (FA landfill offsite; BA and FGD interim ponds, then offsite LF)	C	44" avg. annual precip. (gross), -4" net; avg. annual temp. = 50°F, range 0° to 100°; frost penetration = 20" per winter season. Triassic shale, sandstones and conglomerates overlying PreCambrian metamorphic bedrock. Deep residual fine-grained soils; Monocacy River alluvium at confluence with Potomac River.(near border with B, in Piedmont Province).	Deep, fine-grained (slow permeability) soils over mixed sedimentary rock units (shale, sandstones, conglomerates) and metamorphic units make for slow groundwater movement in a complex pattern. Net evaporation and moderate frost action limit local groundwater flow.
Allen - Duke Power/Gaston County, NC (near Charlotte), on Lake Catawba (27 groundwater wells)	A-	Carboniferous metamorphic bedrock, probably overlain by some alluvium (Piedmont).	Ample net precipitation should provide infiltration, not impeded by frost action, sufficient to support local groundwater flow. Very deep regular silty residual soils furnish medium for flow over underlying metamorphosed sedimentary bedrock. Numerous existing wells support analysis of flow system.

Table 3.2.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Belews Creek - Duke Power/ Stokes County, NC, 20 miles ± NNE of Winston-Salem (near [?] small stream.	B-	Triassic shales, sandstone and conglomerates, over metamorphosed lower Paleozoic units near Blue Ridge Province (Piedmont).	Only moderate frost action should not impede infiltration which should be ample (significant net precipitation) to support groundwater flow locally. Mixed shales, sandstones and conglomerates over lower metamorphosed units, beneath residual soil, may complicate groundwater flow and analysis.
Buck - Duke Power/Rowan County, NC, NW of High Rock Lake, near Salisbury, NC (Yadkin River?)	B	Igneous intrusive bedrock (Paleozoic), maybe PreCambrian (Piedmont).	Significant net precipitation and only moderate frost action should furnish infiltration sufficient to support local groundwater flow. Intrusive igneous bedrock (low permeability) beneath residual soil may create conditions for contained, simple groundwater system. Site-specific data needed.
Cape Fear - Carolina P&L/ Chatham County, NC, on Haw River (?) near border of Piedmont; 20+ miles SW of Raleigh	B+	Carboniferous metamorphosed bedrocks, shales-slates, sandstones near border of Piedmont/Coastal Plain.	Only moderate frost action but ample net precipitation should support local groundwater flow. Mixed residual soils with some alluvium over metamorphosed sedimentary bedrock gives conditions for flow which may be difficult to evaluate.
Cliffside - Duke Power/ Cleveland County, NC, SW of Shelby, NC, near NC-SC border on Broad River (?)	C	PreCambrian/Paleozoic metamorphics, some igneous intrusives, may be alluvium at Broad River (in Piedmont, within 10 miles of Blue Ridge).	Residual soils and possibly alluvium over metamorphic bedrock units broken by igneous intrusions make for a very complex flow system. Ample net precipitation and infiltration should provide local groundwater flow.
Dan River - Duke Power/ Rochingham County, NC, near NC-VA border, due west 10 miles ± from Danville, VA (Leaksville, NC)	C	Triassic sedimentaries over Paleozoic metamorphics (Complex); in Piedmont, near Blue Ridge.	Net precipitation should cause ample infiltration, not impeded by only moderate frost penetration. Residual soils developed from sedimentary bedrock units, over metamorphosed units, create a very complex situation for groundwater flow.
Lee - Carolina P&L/Wayne County, NC, SE from Raleigh Durham, near Goldsboro, about 40 miles Neuse River (?)	B+	Tertiary-Cretaceous sandstone, shale and siltstone, probably unconsolidated deposits (Coastal Plain).	Coastal Plain soils over layered bedrock of sandstone, shale and siltstone make for possibly understandable flow conditions. Only moderate frost action should not impede infiltration seriously, and net precipitation should be sufficient to support groundwater flow locally.
Marshall - Duke Power/Catawba County, NC, 20-30 miles NNW of Charlotte, NC on Lake Norman	B-	Paleozoic igneous intrusive (mid-Piedmont).	Location adjacent to Lake Norman may complicate flow system. Precipitation should be sufficient to support local groundwater flow. Only moderate frost penetration should not impede infiltration. Intrusive igneous bedrock should provide tight basement below residual soils and alluvium, but flow may be affected locally by discontinuities in bedrock.

Table 3.2.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Riverbend - Duke Power/Gaston County, NC, 5-10 miles west of Charlotte, on Lake Catawba	B-	Paleozoic igneous intrusives surrounded by carboniferous metamorphics.	Net precipitation should support local groundwater flow, unimpeded by frost action. Intrusive igneous bedrock beneath residual soil (and alluvium near Lake Catawba in places) may be relatively impervious but erratically broken; flow system may be difficult to interpret.
Roxboro - Carolina P&L/Person County, NC, 20 miles ± due north of Durham	C	Carboniferous metamorphics with igneous intrusives (Complex) (Piedmont).	Deep mixed residual soils developed over metamorphosed sedimentary rock units interrupted by igneous intrusive units make for an extremely complex flow system which may be impossible to monitor and evaluate.
Sutton - Carolina P&L/ New Hanover County, NC, near Wilmington, Cape Fear River (?) (50" precip.)	A-	Quaternary over Tertiary units, sandstone, shale and limestone with overlying unconsolidated solids (Coastal Plain).	More than ample net precipitation with only slight frost action creates conditions favorable to local groundwater flow. Deep coastal soils of sandy nature over sedimentary rocks could furnish relatively simple flow media, although sequence of rock units (sandstone, shale, limestone) may complicate situation.
Eddystone		Inadequate data for geotechnical evaluation.	
Titus - Metropolitan Edison/ Berks County, PA, 40°-18'-21" N, 75°-54'-13" W (BA sluiced to tank, dewatered, then landfilled; FA landfilled)	C	45" avg. annual precip. (gross), 5" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 20" per winter season. Landfill is 35' thick; "clay and shale" under landfill. Three monitoring wells. Bedrock map shows Cambrian limestones. Residual soil.	Net precipitation is adequate to provide infiltration although inflow is impeded by frost action during winter months. Clay subsoils under landfill, over limestone bedrock (leakage into solution channels?) may create constrained, slow, complex groundwater flow almost impossible to evaluate.
Canadys - SC Electric & Gas/ Colleton County, SC (Edisto River (?) at Canadys, SC, 50 miles NW of Charleston)	C	Tertiary sediments.	Only sparse data available on subsoils, but area is underlain by residual soils developed from sedimentary bedrock units. Ample net precipitation and slight frost action should create significant infiltration and local groundwater flow. Possibly very complex flow system.
Jefferies - SC Pub. Serv. Auth./ Berkeley County, SC (Cooper River (?), N of Charleston, SC	B-	Triassic soils and shales (not favorable). (Coastal Plain)	Mixed alluvium and residual soils of low permeability developed over shale bedrock may make this site difficult but not impossible to evaluate. Ample local groundwater flow from net precipitation; negligible frost action should not impede infiltration.
Lee - Duke Power/Anderson County, SC (Reedy River (?), 20 miles south of Greenville, SC	C	Paleozoic/PreCambrian metamorphics-metasediments (Complex); maybe alluvial surface soils (Piedmont).	Residual soils and some alluvium over mixed metamorphic-metasedimentary rock units make for an extremely complex flow situation. Ample precipitation and only moderate frost action should provide infiltration sufficient to supply local groundwater.

Table 3.2.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
McMeekin - SC Electric & Gas/ Lexington County, SC (near Columbia; maybe Lake Norman)	C-	Very complex geology--igneous and metamorphic bedrock (bad bet). (Right on Fall Line between Piedmont and Coastal Plain.)	Very complex structure of mixed igneous and metamorphic bedrock beneath irregular residual soils. Very complex flow system in all probability. Ample groundwater supplies from precipitation.
Robinson - Carolina P&L/ Darlington County, SC (near Florence, SC, 60 miles ± ENE of Columbia)	B	Cretaceous sandstones, shales and conglomerates (Coastal Plain).	Coastal Plain unconsolidated sediments over sandstone, shale and conglomerate bedrock may provide pervious simple flow media, but sequence of rock units may be complex. More than ample net precipitation infiltration and groundwater flow locally.
Urquhart - SC Electric & Gas/ Aiken County, SC (near Aiken, SC, 50 miles SW of Columbia)	C-	Super complex geology (bad bet). (Near Fall Line between Piedmont and Coastal Plain.)	Extremely complex sequence of bedrock units of igneous and metamorphic nature, beneath irregular soil cover. High net precipitation and negligible frost action make for ample infiltration, local groundwater flow.
Wateree - SC Electric & Gas/ Richland County, SC (on Wateree River, 20 miles east of Columbia)	B+	Cretaceous sandstone and shale, maybe some Tertiary sedimentary rocks (Coastal Plain).	Pervious unconsolidated Coastal Plain sediments over sedimentary bedrock (sandstone and shale) should provide relatively simple flow system unless bedrock system causes flow anomalies (leakage into sandstone or perching on shale). More than ample net precipitation and infiltration, with negligible frost action, should give ample local groundwater flow.
Winyah - SC Pub. Serv. Auth./ Georgetown County, SC (on coast of Winyah Bay, 60 miles NE of Charleston)	A-	Quaternary alluvium (favorable). (Coastal Plain)	Very thick, pervious Coastal Plain sediments over deep sedimentary bedrock units. High precipitation and negligible frost penetration should yield ample infiltration and copious local groundwater flow. This may be a site with a simple, easily monitored groundwater system.
Bremo Bluff - VA Elec. & Power/ Fluvanna County, VA (SE of Charlottesville) (5' brown silt clay lenses over 14' of clay over rock)	B-	Very complex geology sequence of igneous intrusives, PreCambrian metamorphics grading	Silt and clay residual soil over thick clay over very complex sequence of bedrock should contain groundwater and leachate, but flow may be difficult to evaluate. Precipitation adequate to provide infiltration, not seriously impeded by frost action, should yield groundwater flow at the site.
Potomac River - Potomac Elec. Power/Alexandria County (Alexandria, VA)	C	Cretaceous sandstone, shale (border between Piedmont and Coastal Plain).	Urban site with mixed soils over interbedded sandstone and shale bedrock units create possibly complex conditions for groundwater flow--very difficult to evaluate. Significant infiltration from precipitation, not impeded by frost action, should provide local groundwater.

3.2.4 Other Site Selection Considerations

3.2.4.1 Discussion

There are a number of regional and site-specific similarities among the sites in the Piedmont and Coastal Plain Region (Region A2). It is not a region characterized by extremes in temperature, and the frost-free period is generally greater than 150 days per year. Neither groundwater nor surface water supplies were reported "critical" in the Second National Water Assessment.(21) A number of areas within this region may be characterized by both extremely high precipitation and relatively pervious soils (noted below). In most cases, potential complications are present in the form of miscellaneous pond influents. Discussion of each plant may be found in Exhibit D.

3.2.4.2 Ratings

Table 3.2.5 presents the ratings for other site selection factors for disposal operations in Region A2.

3.2.5 Candidate and Back-up Sites

In Region A2 the targeted number of sites were:

- candidate sites: one or two;
- back-up sites: up to one.

Details on the assessments from engineering/technological, hydrogeologic, and other viewpoints were presented in Tables 3.2.2 through 3.2.5. Taking all of these into account, the investigators evaluated the more promising ones to arrive at recommendations. Given the predominance of combined fly and bottom ash ponding as a mode of disposal, it was clear that the primary candidate and back-up sites should employ this mode of disposal. Consequently, the primary effort focused on selecting the most suitable candidates for combined fly and bottom ash ponding. In addition, this region had one unlined FGD ponding operation that was atypical but represented potentially higher impact disposal practice. Hence, this was tentatively recommended as a candidate.

The recommended candidate and back-up sites were:

Waste Type/Disposal Method	Candidate Sites	Back-up Sites
Coal Ash		
• Combined Fly and Bottom/Pond (UL)	Allen	Sutton
FGD Wastes		
• FGD/Pond (UL) Combined Fly and Bottom/Pond (?)	} Winyah	---

Table 3.2.6 provides an overview on these sites' characteristics. A brief description of these sites follows.

Table 3.2.5

OTHER SITE SELECTION RATINGS FOR DISPOSAL OPERATIONS IN THE PIEDMONT REGION (REGION A-2)

REGIONAL/GENERIC FACTORS | SITE-SPECIFIC FACTORS

Plant & Utility	Total Rating (+ and -)	Climate			Contaminant Migration Factor (Climate and Soils) (+)	Water Use		Setting		Mitigative Controls			Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or -)
		Temp. >7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)		G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)			
Harlee Br., Ga. Power	BA/FA Pond 1+	0	+	0	0	0	0	NA	NA	0	0	0	+	NA	-
McDonough, Ga. Power	BA/FA Pond 1+	0	+	0	0	0	0	NA	NA	0	0	0	NA	NA	NA
Yates, Ga. Power	BA/FA Pond 1+	0	+	0	0	0	0	NA	NA	0	0	0	+	NA	-
Allen, Duke Power	BA/FA Pond 3+	0	0	0	0	0	0	+	+	0	0	0	++	0	-
Belews Cr., Duke Power	BA/FA Pond 1+	0	0	0	0	0	0	0	+	0	0	0	+	NA	-
Buck, Duke Power	BA/FA Pond 1+	0	0	0	0	0	0	NA	+	0	0	0	+	NA	-
Cliffside, Duke Power	BA/FA Pond 1+	0	0	0	0	0	0	NA	+	0	0	0	+	NA	-
Dan River, Duke Power	BA/FA Pond 2+	0	0	0	0	0	0	NA	+	0	0	0	++	NA	-
Marshall, Duke Power	BA/FA Pond 1+	0	0	0	0	0	0	NA	+	0	0	0	+	NA	-
Riverbend, Duke Power	BA/FA Pond 1+	0	0	0	0	0	0	NA	+	0	0	0	+	NA	-
Lee, Duke Power	BA/FA Pond 2+	0	+	0	0	0	0	NA	+	0	0	0	+	NA	-
Cape Fear, Carolina P&L	BA/FA Pond 2+	0	+	0	NA	0	0	NA	NA	0	0	0	+	NA	NA

Table 3.2.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and −)	Temp. ≥7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or −)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) − No Limit (+)	Complicating Factors (− or =)
Lee, Carolina P&L	BA/FA Pond 3+	0	+	0	+	0	0	NA	NA	0	0	0	+	NA	NA
Roxboro, Carolina P&L	BA/FA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	NA
Sutton, Carolina P&L	BA/FA Pond 4+	0	+	0	+	+	0	NA	NA	0	0	0	+	NA	NA
Robinson, Carolina P&L	BA/FA Pond 2+	0	0	0	+	0	0	NA	NA	0	0	0	+	NA	NA
Canadys, S.C. El.&Gas	NA 3+	0	+	0	+	0	0	NA	NA	NA	NA	NA	+	NA	NA
McMeekin, S.C. El.&Gas	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Urquhart, S.C. El.&Gas	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Wateree, S.C. El.&Gas	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Jefferies, S.C.Pub.Ser.	NA 2+	0	+	0	NA	0	0	NA	NA	NA	NA	NA	+	NA	NA
Winyah, S.C.Pub.Ser.	FGD Pond 4+	0	+	0	+	0	0	NA	NA	0	0	0	NA	++	NA
Bremo Bluff, VEPCO	BA/FA Pond 1−	0	0	0	0	0	0	−	NA	0	0	0	+	NA	−
Potomac River, Potomac El.	BA/FA Fill 1+	0	0	0	0	0	0	NA	NA	+	NA	NA	NA	NA	NA

Table 3.2.3 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. ≥7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or -)
Eddystone, Phila. El.	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	+	NA
Indian River, Delmarva P&L	BA/FA Pond 1-	0	0	0	0	0	0	NA	NA	0	0	0	NA	NA	-
Dickerson, Potomac El.	Int. Pond/Fill *	0	0	0	0	0	0	NA	NA	+	0	0	NA	NA	-
Titus, Metro Edison	BA/FA Fill 3+	0	0	0	0	0	0	NA	NA	+	0	0	++	NA	NA

Key: NA = Information not available
0 = Not applicable
* = Sum of + and - is zero
ppt. = Precipitation
G.W. = Groundwater
S.W. = Surface water

Note: Rating methodology is described in Section 2.8, information on plants is summarized in Exhibit D.

Table 3.2.6

RECOMMENDED CANDIDATE AND BACK-UP SITES - PIEDMONT AND COASTAL PLAIN - REGION A2

	Candidates	Description	Assessment of Disposal Operations	Geotechnical/Hydrogeologic Considerations	Other Factors
1	Allen Plant Duke Power Gaston County, NC	1155-Mw plant started up in 1957. Combined fly and bottom ash to a pond.	Technically typical and excellent disposal operation. 2 1/2+	Carboniferous metamorphic bedrock, probably overlain by some alluvium (Piedmont). A-	Outstanding baseline data; typical practice in typical setting in region. 3+
2	Winyah (Tentative) S. Carolina Public Service Georgetown, SC	630-Mw plant started up in 1975. FGD wastes to a pond. Combined fly and bottom ash probably ponded.	Employs FGD system and disposes FGD waste in unlined ponds 3 1/2+	Quaternary alluvium (favorable) Coastal Plain). A-	Only example of unlined FGD ponding in coastal location. Atypical but defines some types of impacts. 4+
	Back-up				
3	Sutton Plant Carolina Power & Light New Hanover, NC	671-Mw plant started up in 1968. Combined fly and bottom ash to a pond	Technically typical and good disposal practice 2 1/2+	Quaternary over Tertiary units, sandstone, shale and limestone with overlying unconsolidated soils (Coastal Plain). A-	Coastal plant with typical disposal practice, relatively good baseline data. 4+

Allen Plant, Duke Power Co.

Allen, of Duke Power, was designated a candidate site. The disposal practice at this site is considered to be typical of the practice at this utility's plants and in the Piedmont and Coastal Plain region as a whole. The outstanding advantages of this site included prior studies providing extensive background data, including special studies on the quality of ash pond influents (coal-pile runoff and boiler cleaning wastes), baseline data on many priority pollutants, and the tentative willingness of the utility to cooperate in the study. The bedrock in this region was considered likely overlain with alluvium and would present a good site for sampling.

Winyah Plant, South Carolina Public Service Authority

Winyah, of South Carolina Public Service Authority, was tentatively designated as a candidate site because it may represent a presently atypical but potentially higher impact disposal practice in the environmentally sensitive coastal area. Information on this plant was very limited in the VERSAR report and the 308 letter submittals. However, it was believed to represent the only instance of non-stabilized FGD waste disposal in an unlined pond in the coastal zone.

Sutton Plant, Carolina Power & Light

Sutton, of Carolina Power & Light, was designated as a back-up site. This plant is in the Coastal Plain and had the apparent advantages of a coastal (potentially high-impact) location, relatively good baseline data, and disposal streams very typical for the region. Water balance data were available and suggested regionally typical amounts and ratios of fly ash sluice/bottom ash sluice/coal-pile runoff/boiler cleaning waste. Iron, copper, and pH were monitored in addition to the standard TSS and oil and grease measurements. The geologic conditions consist of Quaternary and Tertiary units with overlying unconsolidated soils. Note that this site was primarily considered as a back-up to Smith in Region A1, another coastal plant with combined fly ash and bottom ash ponding.

Some other sites of potential interest in this region (not in any special order) were:

- Harlee Branch, Georgia Power
- Cape Fear, Carolina Power & Light
- Lee, Carolina Power & Light
- Robinson, Carolina & Light

3.3 REGION B: APPALACHIAN REGION

3.3.1 Background

The Appalachian Region extends from northern Alabama to northern New York along the Appalachian Mountains and generally includes the mountainous upland regions of the eastern United States. It includes northern Alabama, northern

Georgia, eastern Tennessee, western North Carolina, eastern Kentucky, western Virginia, West Virginia, the eastern half of Ohio, western Maryland, and most of Pennsylvania and New York.

As of 1977, the region had 76 coal-fired (greater than 80% of power generated from coal) power plants with a total capacity of 63,582 Mw. Fifty-five of these plants, with a capacity of 61,368 Mw, had individual capacities of greater than 200 Mw and are considered further in this section. Table 3.3.1 summarizes the baseline data for these 55 plants. They are generally located (a) along the Tennessee River and its tributaries in Tennessee and Alabama; (b) along the Ohio/Pennsylvania border.

Plant generating capacities ranged from a low of 215 Mw to a high of 3498 Mw. Twenty-three of the plants had capacities of 200 to 700 Mw; five fell int he 700-to-1000 Mw range; twenty-one had capacities of 1000 to 2000 Mw; and six were larger than 2000 Mw. As of 1979, eleven plants had start-up dates* of more than 30 years prior; thirty-six were started up 10 to 30 years prior; and eight had start-up dates of less than ten years prior. Of the six operational FGD systems in this region, five were less than five years old, while the sixth was started up in 1973.

This physiographic region and the prevailing climatic conditions are described in detail in Exhibit C. The average annual temperatures vary from approximately 15°C (60°F) in northern Alabama, to approximately 7°C (45°F) in northern New York. Average annual rainfall varies from approximately 102 cm (40 in.) to about 140 cm (55 in.). The severe relief in this region produces local extremes of both precipitation and climatic variations. Maximum temperatures in this region are approximately 35 to 38°C (95 to 100°F) with average minimum temperatures from approximately -26°C (-15°F) to approximately -18°C (0°F). The surficial deposits in this region consist of residual soils developed from the underlying sedimentary and metamorphosed bedrock, except that local alluvial deposits are found along the deeply incised streams which cut through the region. Frost penetration in this region ranges from less than 25 cm (10 in.) in the southern areas to more than 102 cm (40 in.) in northern New York State.

3.3.2 Assessment of Disposal Operations

3.3.2.1 Categorization of Disposal Operations

Table 3.3.2 presents summary data on disposal methods in Region B.

The utility operations of the Appalachian Region typically employ one or more of seven basic disposal practices for fly ash, bottom ash, and FGD waste:

- single-step pond disposal for fly ash,
- single-step pond disposal for bottom ash,

---

*Date on which coal became the primary source of fuel.

Table 3.3.1

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN APPALACHIAN REGION (B) OF THE U.S.

Plane Name	Utility Name	Capacity (Mw)[b,e]		State	County	Start-up Date		Waste Type[f]	Disposal Method[e,f]
		Nameplate Generating	FCD Scrubbed			Plant[c,d]	FCD[e]		
Gaston*	Alabama Power	2,012	--	AL	Shelby	5/60	--	Comb. Fly & Bottom	Pond(UL)
Gorgas*	Alabama Power	1,486	--	AL	Walker	-/29	--	Comb. Fly & Bottom	Pond(UL)
Widows Creek*	Tennessee Valley Auth.	1,977	550	AL	Jackson	7/52	1/78	FCD Comb. Fly & Bottom	Pond(UL) Pond(UL)
Bowen*	Georgia Power	3,498	--	GA	Bartow	10/71	--	Comb. Fly & Bottom	Pond(UL)
Hammond*	Georgia Power	953	--	GA	Floyd	6/54	--	Comb. Fly & Bottom	Pond(UL)
Big Sandy*	Kentucky Power	1,096	--	KY	Lawrence	1/63	--	Fly Ash Bottom Ash	Pond(UL) Interim Pond(UL); Landfill(UL)
Asheville*	Carolina Power & Light	413	--	NC	Buncombe	5/64	--	Comb. Fly & Bottom	Pond(UL)
Milliken	New York State Electric & Gas	270	--	NY	Tompkins	-/55	--	NA	NA
Ashtabula*	Cleveland Electric Illum.	640	--	OH	Ashtabula	-/49	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL)
Avon Lake*	Cleveland Electric Illum.	1,275	--	OH	Lorain	11/49	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL)
Burger*	Ohio Edison	544	--	OH	Belmont	1/44	--	Fly Ash Bottom Ash	Interim Pond(UL); Landfill(offsite) Interim Pond(UL); Landfill(off-site)/sold
Cardinal*	Cardinal Operating	1,880	--	OH	Jefferson	-/67	--	Fly Ash Bottom Ash	Pond(UL) Interim Pond(UL); sold
Conesville*	Columbus & Southern Ohio Electric	1,678	822	OH	Coshocton	2/57	2/77	Fly/FGD(IUCS) Comb. Fly & Bottom	Landfill(UL) Pond(UL)
Eastlake*	Cleveland Electric Illum.	1,257	--	OH	Lake	9/53	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL): Landfill(UL)
Gavin*	Ohio Electric	2,600	--	OH	Gallia	10/74	--	Fly Ash Bottom Ash	Pond(UL) Pond(CS)
Kyger Creek*	Ohio Valley Electric Coop.	1,086	--	OH	Gallia	2/55	--	Fly Ash Bottom Ash	Pond(UL) Interim Pond(UL);sold
Lake Shore*	Cleveland Electric Illum.	518	--	OH	Cuyahoga	6/62	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL)
Muskingum*	Ohio Power	1,529	--	OH	Morgan	-/53	--	Fly Ash Bottom Ash	Pond(UL) Pond(UL)
Niles*	Ohio Edison	250	--	OH	Trumbull	1/54	--	Fly Ash Bottom Ash	Pond(UL) Interim Pond(UL); sold
Poston*	Columbus & Southern Ohio Electric	232	--	OH	Athens	10/49	--	Comb. Fly & Bottom	Pond(UL)

Table 3.3.1 (continued)

PRELIMINARY LISTING OF POTENTIAL POWER PLANT^a SITES IN APPALACHIAN REGION (B) OF THE U.S.

Plant Name	Utility Name	Capacity (Mw)^{b,e}		State	County	Start-up Date		Waste Type^f	Disposal Method^{e,f}
		Nameplate Generating	FGD Scrubbed			Plant^{c,d}	FGD^e		
Sammis*	Ohio Edison	2,303	--	OH	Jefferson	8/59	--	Fly Ash Comb. Fly & Bottom	Landfill(off-site) Interim Pond(UL); Landfill(off-site)
Armstrong	West Penn Power	326	--	PA	Armstrong	4/58	--	NA	NA
Bruce Mansfield	Pennsylvania Power	1,834	1,834	PA	Beaver	4/76	6/76	Fly/FGD(Dravo) Bottom Ash	Pond(UL) Pond(?)
Brunner Island*	Pennsylvania Power & Light	1,558	--	PA	York	6/61	--	Comb. Fly & Bottom	Pond(UL)
Cheswick*	Duquesne Light	565	--	PA	Allegheny	10/70	--	Fly Ash Bottom Ash	Landfill(mine) Hydrobin; Landfill(UL)/sold
Conemaugh*	Pennsylvania Electric	1,872	--	PA	Indiana	5/70	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL)
Elrama*	Duquesne Light	510	510	PA	Washington	6/52	10/75	Comb. Fly & Bottom Fly/FGD(CSI)	Interim Pond(UL); Landfill(UL)(off-site) Landfill(UL)(off-site)
Hatfield	West Penn Power	1,728	--	PA	Greene	11/69	--	NA	NA
Homer City*	Pennsylvania Electric	2,012	--	PA	Indiana	8/69	--	Fly Ash Bottom Ash	Landfill(UL) Hydrobin; Interim Pond(UL); Landfill(UL)
Keystone*	Pennsylvania Electric	1,872	--	PA	Armstrong	1/67	--	Fly Ash Bottom Ash	Landfill(UL) Hydrobin; Interim Pond(UL); Landfill(UL)
Mitchell	West Penn Power	448	--	PA	Washington	8/63	--	NA	NA
Montour*	Pennsylvania Power & Light	1,641	--	PA	Montour	3/72	--	Comb. Fly & Bottom	Pond(UL)
New Castle	Pennsylvania Power	425	--	PA	Lawrence	5/39	--	NA	NA
Phillips*	Duquesne Light	411	410	PA	Allegheny	1/43	7/73	Comb. Fly & Bottom Fly/FGD(IUCS)	Interim Pond(UL); Landfill(UL) Landfill(UL)
Portland*	Metropolitan Edison	426	--	PA	Northhampton	-/58	--	Fly Ash Bottom Ash	Landfill(UL) Hydrobin; Landfill(UL)/sold
Seward*	Pennsylvania Electric	280	--	PA	Indiana	4/57	--	Comb. Fly & Bottom	Interim Pond(UL); Landfill(UL)
Shawville*	Pennsylvania Electric	625	--	PA	Clearfield	3/54	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL)
Sunbury*	Pennsylvania Power & Light	410	--	PA	Snyder	9/49	--	Fly Ash Bottom Ash	Pond(UL) Pond(UL)

Table 3.3.1 (concluded)

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN APPALACHIAN REGION (B) OF THE U.S.

		Capacity (Mw)[b,e]				Start-up Date			
Plant Name	Utility Name	Nameplate Generating	FGD Scrubbed	State	County	Plant[c,d]	FGD[e]	Waste Type[f]	Disposal Method
Bull Run*	Tennessee Valley Auth.	950	--	TN	Anderson	6/67	--	Comb. Fly & Bottom	Pond(UL)/sold
Kingston*	Tennessee Valley Auth.	1,723	--	TN	Roane	2/54	--	Comb. Fly & Bottom	Pond(UL)
Sevier*	Tennessee Valley Auth.	846	--	TN	Hawkins	7/55	--	Comb. Fly & Bottom	Pond(UL)/sold
Watts Bar*	Tennessee Valley Auth.	240	--	TN	Rhea	2/42	--	Comb. Fly & Bottom	Pond(UL)
Clinch River*	Appalachian Power	712	--	VA	Russell	9/58	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL)
Glen Lyn*	Appalachian Power	337	--	VA	Niles	6/44	--	Fly Ash Bottom Ash	Interim Pond(CS); Landfill(CS) Interim Pond(UL); sold
Albright	Monongahela Power	278	--	WV	Preston	9/52	--	NA	NA
Amos*	Appalachian Power	2,932	--	WV	Kanawha	9/71	--	Fly Ash Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL) Pond(UL)/sold
Fort Martin	Monongahela Power	1,152	--	WV	Monongahela	10/67	--	NA	NA
Harrison	Monongahela Power	1,368	--	WV	Harrison	12/72	--	NA	NA
Kammer*	Ohio Power	712	--	WV	Marshall	-/58	--	Fly Ash Bottom Ash	Pond(UL) Interim Pond(UL); Landfill(off-site)
Kanawha River*	Appalachian Power	439	--	WV	Kanawha	7/53	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(AL); sold
Mitchell*	Ohio Power	1,632	--	WV	Marshall	-/71	--	Fly Ash Bottom Ash	Pond(UL) Pond(AL)
Mt. Storm	Virginia Electric & Power	1,662	--	WV	Grant	9/65	--	NA	NA
Pleasants	Allegheny Power Systems	625	519	WV	Pleasants	3/79	3/79	Fly Ash Bottom Ash FGD (Dravo)	? ? Pond(UL)
Sporn*	Central Operating	1,105	--	WV	Mason	-/50	--	Fly Ash Bottom Ash	Pond(UL) Interim Pond(UL);sold
Willow Island	Monogahela Power	215	--	WV	Pleasants	2/49	--	NA	NA

Footnotes follow Table 3.1.1

CSI = Conversion Systems, Inc.

Table 3.3.2

MATRIX OF FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS

<200 Mw IN THE APPALACHIAN REGION (B) OF THE UNITED STATES IN 1979[a]

Type of Waste	Number of Plants		
	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	10	14	3
Bottom ash only	12	2	12
Combined fly and bottom ash	14	–	4
FGD waste only	1	–	–
Mixed fly ash and FGD waste	–	–	–
Mixed bottom ash and FGD waste	–	–	–
Mixed fly ash and FGD waste (stabilized)	2	3	–
Mixed fly ash, bottom ash, and FGD waste	–	–	–

---

[a] Coal-fired plants (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal.

Source: Compiled by Arthur D. Little, Inc. based on Utility Plant Data Survey Sheets Used in developing reference 1.

- single-step pond disposal for combined fly and bottom ash,
- single-step landfill disposal of fly ash,
- interim pond/landfill disposal of bottom ash,
- single-step pond disposal of FGD waste co-disposed with fly ash, and
- single-step landfill disposal of FGD waste co-disposed with fly ash.

Ponding was the most typical type of disposal mode practiced in this region. In 1979, a total of 28 plants practiced some form of separate and/or combined fly and bottom ash disposal in ponds. The majority of the ponds were unlined. The next most prevalent disposal mode in this region was interim ponding followed by landfilling of coal ash, which was practiced by a total of 18 plants. Out of those 18, 12 plants employed this disposal practice for bottom ash only. The third most prevalent disposal mode in this region was the landfilling of coal ash or stabilized FGD wastes, which was practiced by a total of 17 plants. Out of the 17, there were 14 plants which landfilled fly ash separately. There was no available information on disposal operations at 10 of the 55 plants at the time of candidate site screening.

Disposal of Coal Ash and FGD Wastes in Ponds

Ponding of fly and bottom ash separately or together remains a dominant disposal mode in this region. Ponding of fly ash separately was practiced at Big Sandy, Cardinal, Gavin, Kyger Creek, Muskingum, Niles, Sunbury, Kammer, and Mitchell. Bottom ash ponding was practiced at Cardinal, Gavin, Hyger Creek, Muskingum, Niles, Bruce Mansfield, Sunbury, Glen Lyn, Amos, Kanawha River, Mitchell, and Sporn. In some cases, bottom ash is dredged from the ponds and then sold. Combined fly and bottom ash ponding was practiced at Gaston, Gorgas, Widows Creek, Bowen, Hammond, Asheville, Conesville, Poston, Brunner Island, Montour, Bull Run, Kingston, Sevier, and Watts Bar. Of those plants employing FGD systems, the ponding of non-stabilized FGD waste was practiced at Widows Creek, while both the Bruce Mansfield and Pleasants plants ponded FGD waste stabilized by the Dravo process.

Disposal of Fly Ash, Bottom Ash, and FGD Wastes in Landfills

Landfilling of fly ash separately, bottom ash separately, and stabilized FGD wastes using the Conversion Systems Inc. (CSI) process is also practiced in this region. Landfilling of fly ash separately is the most prevalent mode of landfill disposal and was practiced at Ashtabula, Avon Lake, East Lake, Lake Shore, Sammis, Cheswick (mine), Conemaugh, Homer City, Keystone, Portland, Shawville, Clinch River, Amos, and Kanawha River. Bottom ash was landfilled separately at the Cheswick and Portland plants. Of those plants employing FGD systems, Conesville, Elrama, and Phillips all practiced landfilling of FGD waste that has been stabilized by the CSI process.

Disposal of Fly Ash, Bottom Ash, and FGD Wastes in Interim Ponds/Landfills

The interim ponding/landfill of fly and bottom ash separately or combined is a prevalent mode of disposal in this region, particularly for bottom ash. Big Sandy, Ashtabula, Avon Lake, Burger, East Lake, Lake SHort Conemaugh, Homer City, Keystone, Shawville, Clinch River, and Kammer practiced this disposal mode for bottom ash. Interim ponding followed by landfilling of fly ash separately was practiced at Burger, Glen Lyn, and Amos. Combined fly and bottom ash was interim ponded and then landfilled at Sammis, Elrama, Phillips, and Seward.

3.3.2.2 Assessment of Disposal Operations

Table 3.3.3 presents the results of the disposal operation assessment rating for Region B. The methodology employed in making this assessment is discussed in Section 2.6. Although a number of these plants looked attractive from a disposal operations assessment, hydrogeologic and ratings based on other site selection factors considerably narrowed the choices. In addition, five plants (Niles, Bull Run, Sevier, Clinch River, and Pleasants) were all eliminated from further consideration due to the disposal sites being less than two years old or the fact that the majority of the plant's coal ash had been sold in recent years.

3.3.3 Geotechnical and Hydrogeologic Considerations

Table 3.3.4 presents an evaluation of geotechnical and hydrogeological considerations and subsequent ratings for the sites in Region B. The methodology employed in making this assessment is presented in Section 2.7.

Section 2.7 ←

3.3.4 Other Site Selection Considerations

3.3.4.1 Discussion

48

The Appalachian Region is not characterized by temperature extremes; none of the 55 plants in the region is likely to experience greater than 7000 degree days per year. Eleven out of the 55 sites in the region are in areas that receive greater than 120 cm (48 in.) of precipitation per year and none receive less than 40 cm (16 in.). Seventeen of the 55 sites are in areas reported to experience less than 150 frost-free days per year. None of the sites in the region combine excessive precipitation with pervious coastal-type soils.

The Second National Water Assessment (21) did not report a significant potential for groundwater overdraft in any of the areas being considered in Region B. Surface water supply was not reported to be critical in any of the areas. Exhibit D contains additional information on the individual plants.

3.3.4.2 Ratings

Table 3.3.5 presents the ratings for other site selection factors for disposal operations in Region B. The methodology is described in Section 2.8 and information on individual plants is presented in Exhibit D.

Table 3.3.3

ASSESSMENT OF DISPOSAL OPERATIONS IN APPALACHIAN REGION (B) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Gaston		1+	1+	0	2+	Extraneous pond influents include cooling tower blowdown and plant sumps.
Gorgas		1 1/2+	1+	0	2 1/2+	Extraneous pond influents include plant sumps and water treatment wastes.
Widows Creek		1 1/2+	2+	0	3 1/2+	FGD waste is ponded separately from coal ash.
Bowen		1 1/2+	1+	0	2 1/2+	Extraneous pond influent is classified as low volume water.
Hammond		1/2+	1+	1/2+	2+	Extraneous pond influent is classified as low volume water.
Big Sandy		1 1/2+	1+	1/2+	3+	Extraneous pond influent is storm water run-off. Bottom ash pond overflow is sent to fly ash pond.
Asheville		1 1/2+	1+	0	2 1/2+	
Milliken		1/2+	NA	1/2+	NA	
Ashtabula		1 1/2+	1+	1/2+	3+	Extraneous pond influent is due to yard drains. Bottom ash ponds are under reconstruction.
Avon Lake		1 1/2+	1+	1/2+	3+	Bottom ash pond is under reconstruction.
Burger		1 1/2+	1+	0	2 1/2+	Most bottom ash was sold in 1978.
Cardinal		1 1/2+	1+	0	2 1/2+	Some bottom ash was sold in 1978. Extraneous influents to bottom ash pond include cooling tower blowdown and wastewater.
Conesville		1 1/2+	2+	1/2+	4+	Landfill is 3 years old.
Eastlake		1 1/2+	1+	1/2+	3+	Landfill is 2 years old.
Gavin		1 1/2+	1+	1+	3 1/2+	Extraneous influents to bottom ash pond include cooling tower blowdown and wastewater.
Kyger Creek		1+	1+	0	2+	
Lake Shore		1 1/2+	1+	1/2+	3+	Plant has 3 landfills at different sites.
Muskingum		1 1/2+	1+	0	2 1/2+	Fly ash pond overflow is sent to bottom ash pond.
Niles	X	1 1/2+	1+	0	X	Most bottom ash was sold in 1978.
Poston		1/2+	1+	1/2+	2+	Extraneous pond influent is coal pile run-off.
Sammis		1 1/2+	1+	1/2+	3+	Extraneous pond influent is coal pile run-off. Pond contains underground springs.
Armstrong		1/2+	NA	NA	NA	
Bruce Mansfield		1/2+	2+	1/2+	3+	FGD is stabilized with Dravo process. Fly ash is simultaneously removed with SO_2.

Table 3.3.3 (continued)

ASSESSMENT OF DISPOSAL OPERATIONS IN APPALACHIAN REGION (B) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Brunner Island		1 1/2+	1+	0	2 1/2+	
Cheswick		1 1/2+	1+	1/2+	3+	Fly ash landfill is a mine. Plant intends to go to dry handling of fly ash.
Conemaugh		1 1/2+	1+	1/2+	3+	Extraneous pond influent is coal pile run-off. Bottom ash pond is 2 years old.
Elrama		1 1/2+	2+	1/2+	4+	FGD system became fully operational in 11/77. Fly ash and FGD is stabilized with CSI process.
Hatfield		1/2+	NA	NA	NA	
Homer City		1 1/2+	1+	1+	3 1/2+	Plant employs a coal cleaning facility.
Keystone		1 1/2+	1+	1/2+	3+	Extraneous pond influent is coal pile run-off.
Mitchell		1/2+	NA	NA	NA	
Montour		1 1/2+	1+	0	2 1/2+	
New Castle		0	NA	NA	NA	
Phillips		1 1/2+	2+	1/2+	4+	Fly ash and FGD stabilized with IUCS process as of 10/77.
Portland		1 1/2+	1+	1/2+	3+	Landfill is an old slate quarry.
Seward		1 1/2+	0	0	1 1/2+	
Shawville		1 1/2+	1+	1/2+	3+	
Sunbury		1+	1+	0	2+	Extraneous pond influents include water treatment and plant wastes.
Bull Run	X	1 1/2+	1+	0	X	All ash was sold in 1978.
Kingston		1 1/2+	1+	0	2 1/2+	
Sevier	X	1 1/2+	1+	0	X	Plant used all ash in 1978.
Watts Bar		1 1/2+	1+	0	2 1/2+	
Clinch River	X	1 1/2+	1+	1+	X	Landfill is < 2 years old.
Glen Lyn		1 1/2+	1+	0	2 1/2+	Landfill was originally part of a fly ash pond. Extraneous influent to bottom ash pond is classified as low volume waste.
Albright		1/2+	NA	NA	NA	
Amos		1 1/2+	1+	1/2+	3+	Landfill for fly ash is < 2 years old and is a quarry.
Fort Martin		1/2+	NA	NA	NA	
Harrison		1/2+	NA	NA	NA	

Table 3.3.3 (concluded)

ASSESSMENT OF DISPOSAL OPERATIONS IN APPALACHIAN REGION (B) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Kammer		1 1/2+	1+	0	2 1/2+	Fly ash disposed in Mitchell plant pond.
Kanawha River		1 1/2+	1+	1/2+	3+	Extraneous influent to bottom ash pond is classified as low volume waste. Bottom ash pond has been renovated 2 years ago. Bottom ash pond is lined with PVC.
Mitchell		1 1/2+	1+	0	2 1/2+	Extraneous influents to bottom ash pond include cooling tower blowdown and low volume waste. Bottom ash pond is lined with polyethylene.
Mt. Storm		1/2+	NA	NA	NA	
Pleasants	X	1/2+	0	1/2+	X	Plant and FGD system is < 2 years old.
Sporn		1 1/2+	1+	0	2 1/2+	Extraneous influents to fly ash pond is classified as low volume waste.
Willow Island		1/2+	NA	NA	NA	

---

[a] Assessment rating system explained in Section 2.6.

Table 3.3.4

GEOTECHNICAL/HYDROGEOLOGIC RATING OF SITES - REGION B

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Gaston - Alabama Power Co./ Shelby County, AL, 33°-10'-0" N, 86°-28'-0" W	C+	54.8" avg. annual precip. (gross), 14" net, avg. annual temp. 65°F, range 10° to 100°; frost penetration = 5" ± max. 15'-30' sandy clay over limestone. On border between Regions A1 and B, Gulf Coastal Plain and Appalachian Plateau Paleozoic marine sedimentary bedrock with overlapping deep residual soil.	Ample net precipitation with shallow frost penetration should provide infiltration ample to support local groundwater flow. However, low permeability sandy clay subsoil should create very slow, minimal groundwater (and leachate) flow while underlying limestone may contain erratically located solution channels to give very complex groundwater flow system.
Gorgas #2 and #3 - Alabama Power Co./Walker County, AL, 33°-37'-52" N, 87°-11'-15" W	B	54.6" avg. annual precip. (gross), 10" approx. net; avg. annual temp. = 60°F, range 10° to 100°; frost penetration = 5" max. In Appalachian Plateau, near Region A1, Gulf Coastal Plain. 10' sandy clay over sand, sandstone or shale. Deep residual soils over Pennsylvania sedimentaries; SS, SH. Pottsville formation.	Shallow, short-lived frost penetration with ample net precipitation should provide infiltration sufficient to support local groundwater flow. Sandy clay subsoil over sandstone or shale bedrock constitutes a situation which may complicate groundwater flow, and sampling and analysis.
Widows Creek - TVA/Jackson County, AL, 34°-53'-25" N, 85°--4'-50" W (on Tennessee River)	C	55" avg. annual precip. (gross), 17" approx. net; avg. annual temp. = 58°F, range 5° to 95°; frost penetration ∿ 15" max. Well into Appalachian Plateau (Region B), at least 50 miles from Gulf Coastal Plain (Region A1). Chattahoochee River. Paleozoic sedimentary bedrock units, LS, Sh. (Pond area is old swamp; very high water table, very irregular subsurface deposits.)	Precipitation is ample at site and frost penetration is only moderate. Pond area is located on old swamp deposits with very high water table in very irregular subsurface materials. Flow system may be complex.
Bowen - Georgia Power/Bartow County, GA (Etowah River) (no soil data)	B	Meta-sediments, complex geology, probably some alluvium (on border between Piedmont and Ridge and Valley).	Only shallow frost penetration should not impede infiltration, which should be ample, from net precipitation. Deep residual soils over complex bedrock situation may make analysis of groundwater flow very difficult.
Hammond - Georgia Power/Floyd County, GA, 34°-15'-25" N, 85°-20'-20" W (near Rome on Coosa River)?	C	53.2" avg. annual precip. (gross), 13" ± net; avg. annual temp. = 60°F, range 0° to 100°; frost penetration = 18" per winter season. Lower Paleozoic LS, Sh and SS. Very complex geology due to orogeny. Residual soils with alluvium near stream. Pond is 38' deep. "Low volume water" inflow to pond.	Significant net precipitation and only moderate frost penetration should support local groundwater recharge. However, mixed residual soils and stream alluvium over very complex bedrock sequence should create very complex flow system almost impossible to monitor and analyze.
Big Sandy - Kentucky Power/ Lawrence County, KY, 38°-11' N, 82°-38' W (10 miles south of Huntington, WV, on Big Sandy River)	B	45" avg. annual precip. (gross), 10" net; avg. annual temp. = 53°F, range -10° to 95°; frost penetration = 18" avg. Silty clay beneath pond. Water table at 15'. Pennsylvanian Sh, SS and coal. Some Big Sandy alluvium.	Ample net precipitation and shallow frost penetration create local recharge to groundwater flow system. Silty clay soils impede flow while interlayering of shale, sandstone and coal rock units may complicate basement flow and render analysis difficult. River alluvium may provide simple flow channel for monitoring.

Table 3.3.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Asheville - Carolina P&L/Buncombe County, NC (at Asheville, Blue Ridge Mountains) (no soil data from VERSAR)	C	PreCambrian, Ocee series of meta-sediments, shales, conglomerates; slightly metamorphosed sed. rocks (Blue Ridge Province).	Net precipitation should be ample to support local groundwater flow and only moderate frost action should not impede infiltration seriously. Residual soils developed over erratically mixed meta-sediments may create a very complex flow system almost impossible to analyze.
Milliken		Inadequate data for geotechnical evaluation.	
Ashtabula - Cleveland Electric/ Ashtabula County, OH, 41°-54'-41" N, 80°-45'-24" W (Pond on Lake Erie; landfill south of town)	B-	37" avg. annual precip. (gross), 0" net; avg. annual temp. = 48°, range -10° to 95°; frost penetration = approx. 20" avg. Glacial deposits of moraines and kames with undifferentiated lake deposits, over Devonian shales.	Significant seasonal precipitation and only moderate frost action make for significant infiltration and recharge to local groundwater flow system. However, mixed fine-grained and coarse glacial and lake bed soils over shale bedrock may make evaluation of complex flow system very difficult.
Avon Lake - Cleveland Electric/Lorain County, OH, 41°-22'-45" N, 81°-58'-35" W	B-	37" avg. annual precip. (gross), 0" net; avg. annual temp. = 48°, range -10° to 95°; frost penetration = 20". Quaternary lake deposits over Devonian shales. 20'+ gray clay beneath landfill.	Fine-grained lake bed soils over shale bedrock make for contained but very slow subsurface flow system. Frost action should impede infiltration during winter months. This situation should be very difficult to evaluate.
R. E. Burger - Ohio Edison/ Belmont County, OH, 39°-54'-35" N, 80°-45'-50" W (on the Ohio River, 102 miles downstream from Pittsburgh at Moundsville, WV)	C	40" avg. annual precip. (gross), 0" net; avg. annual temp. = 50°, range -10° to 95°; frost penetration = 20" avg. Upper Pennsylvanian and Permian bedrock including Pittsburgh Coal formation, with sandy Ohio River alluvium over bedrock. Bedrock contains SS, Sh, LS, with coal strata. 15'± to water table.	Residual soils on uplands and river alluvium near stream, over bedrock of sandstone, shale and limestone (with coal seams) may produce complex flow pattern and complex groundwater chemistry. Water table at shallow depth reflects ample local recharge from precipitation. Annual dredging of ponds complicates interpretation of system.
Cardinal, Cardinal Operating - Ohio Power/Clermont County, OH, 40°-15'-00" N, 80°-38'-45" W (77 miles downstream from Pittsburgh, on Ohio River)	B+	40" avg. annual precip. (gross), 6" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 20" avg. Upper Pennsylvanian and Permian bedrock, including Pittsburgh Coal formation, with sandy Ohio River alluvium over bedrock, with modern alluvium near surface. SS, Sh, LS with coal, in bedrock. 10'-15' silty clay below pond 1, over bedrock; 25'-30' silty clay, over sand and gravel, below pond 2; no landfill.	Silty clay soil below ponds will retard flow, while sandstone bedrock (or alluvium below clay) will permit rapid flow. Other bedrock units may have little permeability or highly localized permeability. Net precipitation is adequate to support local groundwater flow; infiltration will not be impeded by frost action.
Conesville - Columbus and S. Ohio Electric/Coshocton County, OH, 40°-11'-15" N, 81°-52'-30" W	C	40" avg. annual precip. (gross), 1" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 20" avg. Pleistocene alluvium/ terrace deposits, with modern alluvium of Muskingum River, over Pennsylvanian SS, LS with coal of Pottsville and Allegheny formations. FGD also. Monitoring wells; data from EPRI monitoring program.	Net precipitation, seasonally high, and only moderate frost action should make for infiltration adequate to support local groundwater flow. Alluvial soils, highly pervious, permit rapid flow of leachate/groundwater. Aquifer is contaminated with emergency discharge of FGD system effluent.

Table 3.3.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Eastlake - Cleveland Electric/ Lake County, OH, 41°-40'-30" N, 81°-27'-10" W (Pond is 41°-44'-40" N, 81°-16'-05" W of landfill)	B-	37" avg. annual precip. (gross), 0" net; avg. annual temp. = 48°F, range -10° to 95°; frost penetration = 20" avg. Undifferentiated (sands, silts, clays) Quaternary lake deposits over Devonian shales. 5'-7' br. silty clay below landfill. Very near Lake Erie. Landfill is 16 miles from plant.	Silty clay lake bed soils over shale should provide a contained but very slow flow system difficult to sample and evaluate in limited time. Precipitation adequate to provide limited local recharge but winter infiltration will be impeded by frost action.
Gavin - Ohio Electric/Gallia County, OH, 82°-11' W, 36°-55' N (on Ohio River, ~ 260 miles downstream from Pittsburgh)	B-	40" avg. annual precip. (gross), 6" net; avg. annual temp. = 55°F, range -5° to 95°; frost penetration = 20". Pennsylvanian limestones, sandstones and shales underlying Ohio River silty, sandy alluvium. 15' brown clay, 5' clay shale below BA pond. FA pond is 2.5 miles miles from plant, at upper elevations in Monongahela formation of LS and SS, with coal seams, covered with residual soil.	Residual soils above limestone, sandstone and coal seams underlie fly ash pond, while clay and clay shale underlie bottom ash pond; this could make for slow flow in soil layers and erratic cross-flow with bedrock units units. Precipitation is adequate to support local recharge to groundwater.
Kyger Creek - Ohio Valley Electric Cooperative/Gallia County, OH, 38°-55' N, 82°-07' W (260 miles downstream from Pittsburgh on the Ohio River)	B+	40" avg. annual precip. (gross), 6" net; avg. annual temp. = 55°F, range -5° to 95°; frost penetration = 20" avg. BA pond underlain by silty clay; 24' to water. Monongahela formation of Pennsylvanian LS, SS with coal seams; overlain by Pleistocene Ohio River sandy alluvium and mixed modern alluvium.	Alluvial and residual soils, some silty clays, over limestones and sandstones, make for irregular flow patterns, difficult to analyze. Precipitation is adequate to support local recharge, impeded only moderately by frost action during winter.
Lake Shore - Cleveland Electric/Cuyahoga County, OH, 41°-32'-07" N, 81°-38'-37" W (Pond is 41°-25'-35" N, 81°-38'-05" W of landfill #1; 41°-26'-40" N, 81°-38'-05" W of landfill #2; and 41°-26'-40" N, 81°-42'-10" W of landfill #3)	C-	37" avg. annual precip. (gross), 0" net; avg. annual temp. = 48°F, range -10° to 95°; frost penetration = 20" avg. Undifferentiated Quaternary lake deposits, with glacial outwash, over Devonian shales. 35' to water table at landfills 1 and 2; FA fill is directly on shale. Two monitoring wells at landfill 1; none at landfill 2; 13 miles to landfill 1; 9 miles to landfills 2 and 3. 40' to water at landfill 3; fill is on shale; no monitoring wells. BA pond at plant. Landfill is 95% garbage with FA and BA mixed.	Plant landfills located directly on shale bedrock with water table at depth make for very difficult interpretation of flow conditions. Refuse mixed with plant wastes confounds analysis of water/leachate quality.

Table 3.3.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Muskingum - Ohio Power/Morgan County, OH, 39°-34'-32" N, 81°-40'-30" W (BA pond is 1.5 miles from plant, on the Muskingum River)	B	40" avg. annual precip. (gross), 6" net; avg. annual temp. = 53°F, range -5° to 95°; frost penetration = 15" to 18". Silty clay below BA ponds and FA ponds. Water table at 10' Monongahela formation of LS, SS, and coals (Pennsylvanian) and Permian LS, SS, and Sh. Fine-grained residual soils over bedrock. All ponds within one mile of plant.	Net precipitation and only moderate frost action should yield local recharge and ample groundwater supplies. Silty clay soils below ponds make flow very slow, difficult to monitor. Underlying rock units differ drastically in permeability; basement flow may be complicated.
Niles - Ohio Edison/Trumbull County, OH, 41°-10'-30" N, 80°-40'-25" W (BA pond, FA pond and retired FA pond are all within 1/2 mile (Youngstown)	B-	35" avg. annual precip. (gross), -5" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 20" avg. 15' to water table below ponds. Glacial deposits (moraines and kames) over Pennsylvanian Pottsville formation of LS, SS, Sh, and coal	Net evaporation, but seasonal precipitation and only moderate frost action combine to yield groundwater at shallow depths. Variable glacial soil deposits, sandy to clayey in texture, over interbedded limestone, sandstone, shale, and coal may create irregular flow pattern difficult to analyze.
Poston - Columbus and S. Ohio Electric/Athens County, OH, 39°-23'-10" N, 82°-11'-02" W (30/70 BA/FA pond) (Athens; Hocking River)	C	40" avg. annual precip. (gross), 1" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 20" per winter season. Pond is 60' deep; below pond, 0-3' silty clay, silt or clay, at 3' sandy shale. Conemaugh formation of LS, SS, Sh, with coal.	Slight net precipatation, seasonal in nature, and only moderate frost action create conditions for significant but limited local infiltration. Deep pond underlain by thin silty clay over sandy shale may create flow conditions very difficult to analyze. Shale is interbedded with limestone and sandstone and contains coal beds.
Sammis - Ohio Edison/Jefferson County, OH, 40°-30'-05" N, 80°-30'-50" W (Pond is 1/3 mile from plant, 53 miles downstream of Pittsburgh on the Ohio River)	C	40" avg. annual precip. (gross), 0" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 18°; 10' to 12' to water table, at pond. Ponds dredged every 6 months, with off-site landfill by contractor. "Underground springs" in pond. Pennsylvania Conemaugh formation of SS, Sh, LS, overlain by fine-grained residual soil on ridges and sandy alluvium near Ohio River.	Precipitation adequate for ample local recharge, not seriously impeded by frost action, to system in alluvium connected hydraulically with the Ohio River. Ponds dredged and off-site landfill make situation extremely complex. Underlying rock units carry water under pressure from uplands; rock units vary in permeability.

Table 3.3.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Armstrong		Inadequate data for geotechnical evaluation.	
Bruce Mansfield		Inadequate data for geotechnical evaluation.	
Brunner Island - Pennsylvania P&L/York County, PA, 40°-05'-11" N, 78°-41'-42" W (BA/FA pond on Susquehanna River)	B+	45" avg. annual precip. (gross), 0" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 20" per winter season. Pond (0.4 miles from plant) is 20'-35' deep; water table at 5' to 15'. Alluvium over conglomerate," beneath pond. Triassic shales, sandstones and conglomerate over Cambrian shales and limestones. Susquehanna River alluvium.	River alluvium over shales, conglomerates and sandstones may provide pervious but leaky (into bedrock) flow medium. High water table (in deep pond) shows precipitation is adequate for copious groundwater flow.
Cheswick - Duquesne Light Co./ Allegheny County, PA (Fly ash goes to abandoned coal mine)		Poz-o-Tec liner; two monitoring wells; 7' to groundwater, below ponds. Inadequate data for geotechnical evaluation.	Data are not sufficient to permit rating, but presence of liner and high groundwater table create system to monitor for effects of bottom ash disposal.
Conemaugh - Pennsylvania Elec./ Indiana County, PA, 40°-22'-59" N, 79°-04'-19" W (on Conemaugh River, near Johnstown; BA pond; LF for FA, coal refuse)	B-	40" avg. annual precip. (gross), 12" net; avg. annual temp. = 48°F, range -10° to 90°; frost penetration = 20' per winter season. Pond is 7' deep; water table at 10'-13'. Below pond, sandy silty to 12', then sand 12' to 15'. Landfill is 160' deep; water table at 12'. Below landfill, silty clay to 6'; graysilt from 6' to 8'; clayey silt and sand 8' to 12.5'. Bedrock is Mississippian shales, sandstones and limestones.	Pervious soils with high water table indicate possibility for meaningful monitoring below bottom ash pond, but silty, clayey soils below landfill may make monitoring difficult in limited time frame. Coal refuse mixed in landfill may complicate interpretation of data.

Table 3.3.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Elrama - Duquesne Light/Washington County, PA, 40°-15'11" N, 79°-54'58" W, ash pond, 40°-14'57" N, 79°-56'27" W, landfill, IUCS, (Poz-o-tec landfill on Youghiogheny River)	B+	44" avg. annual precip. (gross), 14" net; avg. annual temp. = 48°F, range -10° to 95°; frost penetration = 20" per winter season. Interim holding ponds for ash and coal pile runoff; 3 monitoring wells for ponds, 4 monitoring wells at landfill. Landfill between river and hillside. Pennsylvanian sandstones and shales with coal (Pittsburgh coal) over Mississippian SS, Sh, LS. Alluvium near stream; residual soil and mine spoil on hillside.	Adequate net precipitation and only moderate frost action should provide local groundwater flow. Coal in limestone, sandstone, shale sequence in hillside beneath fill may affect groundwater quality. Underlying alluvium may provide good monitoring medium.
Hatfield		Inadequate data for geotechnical evaluation	
Homer City - Pennsylvania Electric/ Indiana County, PA, pond LF - 40° - 30'50" N, 79° - 11'54" W, ponds (BA cleaned out, FA landfill)	B-	40" avg. annual precip. (gross), 12" net; avg. annual temp. = 48°F, range -10° to 95°; frost penetration = 20" per winter season. Pond is 12' deep, 13' to water table. Below pond: sandy clay to 5'; weathered SS 5 to 8"; weathered Sh from 8' to 11'. Landfill is 175' deep (?); water table at 7'. Below landfill, similar soils as for pond, 2 monitoring wells at landfill, one well near pond. Pennsylvanian SS, Sh; residual soils.	Net precipitation adequate to support local groundwater flow; infiltration not seriously impeded by frost action. Sandy clays with high water table over sandstone and shale at shallow depths make for very slow and possibly irregular flow pattern, difficult to evaluate.
Keystone - Pennsylvania Electric/ Armstrong County, PA, 40° - 39' 16" N, 79° - 21'10" W, (BA ponds landfill)	B-	40" avg. annual precip. (gross), 12" net; avg. annual temp. = 48°F, range -10° to 95°; frost penetration = 20" per winter season. Pond (BA) is 0.2 miles from plant. Landfill 80/20 FA/BA is 80' thick; water table 25' to 55'. Below landfill, 30' of silty clay, two (2) monitor wells at landfill. Pennsylvanian SS, Sh; residual soil.	Deep silty clay soils over sandstone and shale rock units, with deep water table may be difficult to evaluate because of very slow flow. Net precipitation should furnish infiltration but clay soils of very low permeability limit recharge.
Mitchell - West Penn Power		Inadequate data for geotechnical evaluation	
Montour - Pennsylvania Power & Light/Mountour County, PA, 41° - 04'34" N, 76° - 39'40" W, (combined BA/FA pond)	C	48" avg. annual precip. (gross), 8" net; avg. annual temp. = 50°F, range -10" to 95°; frost penetration = 30" per winter season. Complex geology - Devonian sedimentary bedrock. Pond is 24% BA, 61% FA, 15% mill rejects. Pond is 35' to 40' deep; below pond, silt-loam, above bedrock.	Limited net precipitation and significant frost action impeding infiltration during winter months may restrict local recharge. Silt loam over shale bedrock in a complex geological sequence may yield constrained but erratic flow around deep pond.

Table 3.3.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Newcastle		Inadequate data for geotechnical evaluation	
Phillips - Duquesne Light/ Allegheny County, PA, 40° -34'13" N, 80° -13'57" W, (FGD also, interim pond LF, Pond 2 is 100% CPR)	B-	44" avg. annual precip. (gross), 14" net; avg. annual temp. = 48°F, range -10° to 95°; frost penetration = 20" per winter season. Pond is 20' deep, 73' to water table. Below pond is 11' sand and gravel, over 3' of clay, over 39' of sandy silty clay, 2 monitoring wells. Landfill is 140' thick; water table at 15'. Silty clay under landfill, 2 monitoring wells. Pennsylvanian SS, Sh; residual soils.	Silty clay over sandstone and shale beneath landfill, with shallow water table, may cause slow flow in system difficult to analyze. More pervious soils below pond overlie clay layers with water table at depth, in a situation more amenable to analysis.
Portland - Metropolitan Edison/Northhampton County, PA, 40° -52'27" N, 75° -11' 55" W, 20/80 BA/FA - LF (Very near Region A-2 and Region C - New Jersey)	C	45" avg. annual precip. (gross), 5" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 30" per winter season.	Low net precipitation and significant frost action limit infiltration and local recharge. Pond area underlain by residual soils over shale and sandstone bedrock units could be monitored, but landfill in "slate quarry" would be impossible to analyze.
Seward - Pennsylvania Electric/Indiana County, PA, 41° -24'10" N, 79° -01'54" W, (on Conemaugh River)	B-	40" avg. annual precip. (gross), 12" net; avg. annual temp. = 48°, range -10° to 90°; frost penetration = 20" per winter season. Pond is 12' deep, landfill is 20/80 BA/FA. Water table is 3' to 13' below landfill. Beneath landfill, 5' clayey silt over 14' silty sand. Pennsylvanian SS, Sh.	Precipitation adequate for recharge and only moderate frost action produce shallow water table. Clayey sil over sand over sandstone or shale presents a physical system with extreme variations in permeability; a system very difficult to monitor and evaluate.
Shawville - Pennsylvania Electric/Clearfield County, PA, 41° -03'49" N, 78° -22' 16" W, BA pond LF, FA, LF, 20/80 BA/FA	C	40" avg. annual precip. (gross), 12" net; avg. annual temp. = 50°F, range -15° to 95°; frost penetration = 30" per winter season. Pond is 12' to 22' deep; water table at 35' below surface at pond. 15' FA/BA fill, over 8' of silty clay over 10' sand and gravel, over sandstone. Landfill water table at 6' to 8'. Below landfill, 3.5' clayey-silt over 3' silty sand over sandstone. Pottsville formation of Pennsylvanian SS, Sh.	Sequence of silt-clay soils over more pervious sands over pervious sandstones may create groundwater flow very difficult to evaluate: slow flow and leachate movement in upper soils with rapid flow (rapid dilution) below.
Sunbury - Pennsylvania Power and Light/Snyder County, PA, 40° -49'55" N, 76° -50'00" W, 2 ponds, BA others; 100% FA, (on the Susquehanna River)	C	40" avg. annual precip. (gross), 0" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 30" per winter season. BA pond is 5' deep; FA pond is 0' to 85' deep. Below ponds, shaley silt loam over shale bedrock. Devonian shales and limestones, residual soils.	No net precipitation and interfering frost action act to limit local groundwater recharge. Shaley silt soil over shale rock makes for slow, erratic flow system. Very deep pond is very difficult to monitor.

Table 3.3.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Bull Run - TVA/Anderson County, TN, 36° -00'04" N, 84° -09'18" W, Clinch River Valley	B-	50" avg. annual precip. (gross), 17" net;, avg. annual temp. = 55°F, range -0° to 95°; frost penetration = 20" per winter season. Cambrian limestones and shales below valleys, with Ordovician limestones below ridges. Deep fine-grained residual soils in valleys, with thin residual soils on hillsides. Water table at 15', pond depth 30'.	Net precipitation and only shallow frost penetration should lead to local groundwater recharge. Fine-grained soils likely below ponds, over bedrock with possible solution channels, may create irregular flow pattern. Pond bottom 5 meters below water table may cause complex flow, difficult to interpret.
Kingston - TVA Steamplant/ Roane County, TN, 84° -30' 21" W	B-	52" avg. annual precip. (gross), 18" net;, avg. annual temp. = 55°F, range -0° to 95°; frost penetration = 22" per winter. Water table at 15', pond depth = 40'. Cambrian limestones and shales below valleys with Ordovician limestones below ridges. Deep fine-grained residual soils in valleys, with thin residual soils on hillsides. No data on soils below ponds.	Fine-grained soils likely below ponds, over bedrock with possible solution channels creat complex flow patterns. Net precipitation and only shallow frost penetration should furnish infiltration adequate to support local groundwater flow; pond bottom 7-8 meters below water table complicates situation.
Sevier - TVA/Hawkins County, TN, 36° -22'11" N, 82° -58' 38" W	C	42" avg. annual precip. (gross), 9" net; avg. annual temp. = 59°F, range 0° to 95°; frost penetration = 20" per winter season. Ordovician limestone bedrock with overlying thin residual soils (clayey). 5'-10' lean clay underlain by Ml-MH compessible silts, beneath pond. Water table at 35'; pond depth = 38'.	Water table above pond bottom, pond underlain by low-permeability clays and silts over bedrock with possible cavities, are factors making flow complex and difficult to analyze. Small net precipitation and moderate frost action tend to create only limited local groundwater recharge.
Watts Bar - TVA/Rhea County, TN, 35° -36'11" N, 84° -46' 47" W (50 miles SW of Knoxville)	C+	53" avg. annual precip. (gross), 18" net; avg. annual temp. = 55°F, range = 0° to 95°; frost penetration = 20" per winter season. Cambrian and Ordovician LS and Sh, deep residual soils.	Net precipitation and slight frost penetration should lead to significant local recharge. Fine-grained residual soils over bedrock with large variations in permeability (shale versus limestone) should create complex flow pattern. Site-specific data are needed from field exploration.
Clinch River - Appalachian Power Co./Russell County, VA, 36° -55'30" N, 82° -11'20" W(2 ponds, fly-ash landfill)	C	45" avg. annual precip. (gross), 15" net; avg. annual temp. = 55°F, range = 0° to 95° frost penetration = 20" per winter season. Cambrian shales below residual soils. Bedrock at 2' to 4' below pond. Fine-grained residual soil. Pond 1 is 50' deep, Pond 2 is 20' deep. Landfill is 100' thick, shale below landfill.	Net precipitation should create groundwater recharge. Very thin thickness of fine-grained soil between disposal zones and bedrock would make it almost impossible to monitor flow of groundwater and leachate (if any).
Glen Lyn - Appalachian Power/Giles County, VA,	C (tentative)	Inadequate data for geotechnical evaluation	The presence of a liner, 8' thick, consisting of clay soil beneath the pond at the site makes for very slow leachate and groundwater flow and could render interpretation difficult. Additionally, the bedrock sequence beneath the site is very complex and could lead to further anomalies in flow. Precipitation should be adequate to furnish potential infiltration, but the fine-grained nature of the surface soil at the site also may limit infiltration and local groundwater recharge.

Table 3.3.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Albright		Inadequate data for geotechnical evaluation	
Amos - Appalachian Power/ Kanawha County, WV, 38° -26'-30" N, 81° -52'-00" W, (on Kanawha River)	C-	45" avg. annual precip. (gross), 13" net; avg. annual temp. = 50°, range -5° to 95°; frost penetration = 20" per winter. Ponds excavated, BA pond 17', w.t. at 15', 40' silty clay, underlain by 15' sand/gravel, over sandstone (below BA pond). Below FA pond - 10' to 20' silty clay over shaly SS, FA pond 140' deep; water table at 15', landfill quarry in shaley SS, 75' deep, 15' to water table. Pennsylvanian Sh, SS and coal of Monongahela formation.	Clay soils over sand/gravel over sandstone, with shallow water table in very deep disposal areas, should be almost impossible to evaluate for water/ leachate flow and quality.
Fort Martin		Inadequate data for geotechnical evaluation	
Harrison		Inadequate data for geotechnical evaluation	
Kammer - Ohio Power/ Marshall County, WV, 39° -50'-14" N, 80° -49'-28" W on Ohio River.	C	37" avg. annual precip. (gross), 6" net; avg. annual temp. = 50°F, range -5° to 95°; frost penetration = 20" per winter. Average 35' to water at abandoned FA pond (28' deep), BA (slag) pond depth unknown, water at 35'; new FA pond 85' deep, water at 10' to 15'. Silty clay below all 3 ponds, below BA pond and old FA pond, sand beneath the silty clay, at new FA pond, rock under silty clay. Pennsylvanian Sh, SS and LS with coal of Monongahela formation.	Very deep ponds underlain by low-permeability soil, over rock in some places and over sand in other locations, with high water table creates a situation very difficult to evaluate. Coal in bedrock may alter groundwater quality.
Kanawha River - Appalachian Power/Kanawha County, WV, 38° -12'-30" N, 81° -25'-30" W, BA pond; FA landfill (both within 0.5 mile of plant)	C	45" avg. annual precip. (gross), 15" net; avg. annual temp. = 50°F, range -5° to 95°; frost penetration = 20" per winter. BA pond 18' deep, 26' to water. At FA landfill, water at 10' to 15', landfill is 30' deep. Below BA pond, 7' alluvial silt. Pennsylvanian sandstones, shales and coal. Fine-grained residual soils with alluvium near river.	Net precipitation with only moderate frost action should support local recharge and infiltration. Landfill deeper than water table would be difficult to monitor. Silty soils over sandstones, shale and coal may yield irregular flow pattern, and discharge from coal seams may alter groundwater quality.

Table 3.3.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Mitchell - Ohio Power/Marshall County, WV, 39°-49'-30" N, 80°-49'-00" W (FA pond, BA pond)	C	40" avg. annual precip. (gross), 15" net; avg. annual temp. = 50°F, range -5° to 95°; frost penetration = 20" avg. per winter. FA pond 85' deep, 10'-15' water table. 5'-15' residual silty clay over bedrock. BA pond 30' deep, 24' to water table. 0-1' topsoil, over 6.5' "variegated" sand and gravel, over bedrock. 24' to water table. Pennsylvanian Sh, SS and LS with coal of Monongahela formation.	Slight net precipitation and moderate frost action limit infiltration somewhat. Variable soils (clay to gravel) over shale, sandstone and limestone bedrock, with pond bottoms below water table, should create very complex flow patterns.
Mt. Storm		Inadequate data for geotechnical evaluation.	
Pleasants		Inadequate data for geotechnical evaluation.	
Sporn - Central Operating/ Mason County, WV (BA pond, 38°-57'-35" N, 81°-55'-10" W, o.25 mile from plant; FA pond, 38°-57'N, 81°-55'W, 0.5 mile from plant	B	40" avg. annual precip. (gross), 6" net; avg. annual temp. = 50°F, range -5° to 95°; frost penetration = 20" avg. per winter. BA pond underlain by fine sand, pond 20' deep, water table at 40'. FA pond underlain by fine sand, pond 34' deep, water table at 40'. Plant located on Ohio River 241 miles downstream from Pittsburgh. Pennsylvania shales, sandstones, and coal overlain by Ohio River alluvium.	Small net precipitation but only moderate frost action should create only limited local recharge. Fine sand under ponds, over shale, sandstone or coal beds, with water table below pond bottoms, may furnish flow milieu amenable to monitoring and analysis.
Willow Island		Inadequate data for geotechnical evaluation.	

Table 3.3.5

OTHER SITE SELECTION RATINGS FOR DISPOSAL OPERATIONS IN THE APPALACHIAN REGION (REGION 3)

REGIONAL/GENERIC FACTORS — SITE-SPECIFIC FACTORS

Plant & Utility	Total Rating (+ and -)	Climate			Contaminant Migration Factor (Climate and Soils) (+)	Water Use		Setting		Mitigative Controls			Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
		Temp. >7000 Degree Days F (+)	ppt. ≤16" (40cm) or ≥48" (120cm) (+)	≤ 150 Frost-Free Days (+)		G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)			
Gaston, AL Power	FA/BA Pond 2+	0	+	0	0	0	0	+	NA	0	0	0	+	NA	-
Gorgas, AL Power	FA/BA Pond *	0	+	0	0	0	0	NA	NA	0	0	0	NA	NA	-
Widows Creek, TVA	FA/BA Pond 5+	0	+	0	0	0	0	NA	+	0	0	0	++	+	NA
	FGD Pond 5+	0	+	0	0	0	0	NA	+	0	0	0	++	+	NA
Bowen, GA Power	FA/BA Pond 2+	0	+	0	0	0	0	NA	0	0	0	0	+	+	-
Hammond, GA Power	FA/BA Pond 2+	0	+	0	0	0	0	NA	NA	0	0	0	+	+	-
Big Sandy, KY Power	FA/BA Pond 1+	0	0	0	0	0	0	+	NA	0	0	0	+	NA	-
	BA Pond 2+	0	0	0	0	0	0	NA	NA	0	0	0	+	+	NA
	BA Fill *	0	0	0	0	0	0	NA	NA	+	0	0	NA	NA	-
Asheville, Carolina P&L	FA/BA Pond 2+	0	+	0	0	0	0	NA	NA	0	0	0	+	NA	NA
Milliken, NY State G&L	NA 1+	0	0	+	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Ashtabula, Cleveland Elec. Illum.	FA/BA Fill 1+	0	0	0	0	0	0	NA	NA	+	0	0	+	NA	-
	BA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	+	-

Table 3.3.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. >7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Avon Lake, Cleveland Elec. Illum.	FA Fill 2+	0	0	0	0	0	0	+	NA	+	0	0	+	+	-
	BA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	+	-
Burger, OH Edison	Ash Ponds 2+	0	0	0	0	0	0	+	NA	0	0	0	+	NA	NA
	Offsite Fill *	0	0	0	0	0	0	NA	NA	+	NA	0	NA	NA	-
Cardinal, Cardinal Operating	FA Pond 4+	0	0	0	0	0	0	+	+	0	0	0	+	+	NA
	BA Pond 3+	0	0	0	0	0	0	+	+	0	0	0	+	+	-
Conesville, Columbus & South. OH Electric	FGD/FA/BA Fill 5+	0	0	0	0	0	0	+	+	+	0	+	+	+	-
	BA Pond 4+	0	0	0	0	0	0	+	+	0	0	0	+	+	NA
Eastlake, Cleveland Elec. Illum.	FA Fill 1+	0	0	0	0	0	0	-	NA	+	0	0	+	+	-
	BA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	+	-
Gavin, OH Electric	FA Pond 2+	0	0	0	0	0	0	NA	NA	0	0	0	+	+	NA
	BA Pond *	0	0	0	0	0	0	-	NA	0	0	0	+	+	-
Kyger Creek, OH Valley Elec. Coop.	FA Pond 2+	0	0	0	0	0	0	+	NA	0	0	0	+	NA	NA
	BA Pond 3+	0	0	0	0	0	0	+	NA	0	0	0	+	+	NA
Lake Shore, Cleveland Elec. Illum.	BA/FA Fill 1-	0	0	0	0	0	0	-	NA	+	0	0	+	NA	--
	BA Pond *	0	0	0	0	0	0	NA	NA	0	0	0	NA	+	-

Table 3.3.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. >7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Muskingum, OH Power	FA Pond 4+	0	0	0	0	0	0	+	+	0	0	0	+	+	NA
	BA Pond 2+	0	0	0	0	0	0	+	+	0	0	0	+	NA	-
Niles, OH Edison	FA Pond 1+	0	0	+	0	0	0	-	NA	0	0	0	+	+	-
	BA Pond 3+	0	0	+	0	0	0	+	NA	0	0	0	+	+	-
Poston, Columbus & South. OH Electric	Offsite Fill 1+	0	0	0	0	0	0	NA	NA	+	NA	0	NA	NA	NA
	FA/BA Pond 2+	0	0	0	0	0	0	NA	NA	0	0	0	+	+	NA
Sammis, OH Edison	FA/BA Fill *	0	0	NA	0	0	0	NA	NA	+	NA	NA	NA	NA	-
	Int. BA/ FA Pond *	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	-
Armstrong, W. PA Power	NA 2+	0	0	+	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Bruce Mansfield, PA Power	FGD Pond 4+	0	0	+	0	0	0	NA	0	0	0	+	+	+	NA
Brunner Isl., PA P&L	FA/BA Pond 2+	0	0	0	0	0	0	+	NA	0	0	0	+	NA	NA
Cheswick, Duquesne Light Co.	FA/BA Fill 4+	0	0	+	0	0	0	NA	NA	+	0	0	+	+	NA
Conemaugh, PA Electric	FA/BA Fill 3+	0	0	+	0	0	0	+	NA	+	0	0	++	NA	—
	BA Pond 2+	0	0	+	0	0	0	NA	NA	0	0	0	+	NA	NA

Table 3.3.5 (Continued)

Plant & Utility	Total Rating (+ and -)	REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate			Contaminant Migration Factor (Climate and Soils) (+)	Water Use		Setting		Mitigative Controls			Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
		Temp. >7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤150 Frost-Free Days (+)		G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)			
Elrama, Duquesne Light Co.	FA/BA Pond 3+	0	0	+	0	0	0	NA	NA	0	0	0	++	NA	NA
	FA/FGD Fill 6+	0	0	+	0	0	0	NA	+	+	0	+	+	++	-
Hatfield, W. PA Power	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Homer City, PA Electric	FA Fill 4+	0	0	0	0	0	0	+	+	NA	+	0	++	NA	-
	BA Pond 3+	0	0	+	0	0	0	NA	NA	0	0	0	NA	++	NA
Keystone, PA Electric	FA Fill 4+	0	0	+	0	0	0	+	NA	+	0	0	++	NA	-
	BA Pond 3+	0	0	+	0	0	0	NA	NA	+	0	0	+	NA	NA
Mitchell, W. PA Power	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Montour, PA P&L	BA/FA Pond 2+	0	+	+	0	0	0	NA	NA	0	0	0	+	NA	-
Newcastle, PA Power	NA 1+	0	0	+	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Phillips, Duquesne Light Co.	FA/BA Pond 4+	0	0	+	0	0	0	+	NA	0	0	0	++	NA	NA
	FA/FGD Fill 4+	0	0	+	0	0	0	+	NA	+	0	+	+	+	—
Portland, Metropolitan Edison	FA/BA Fill 2+	0	0	0	0	0	0	-	NA	+	0	0	++	NA	NA
Seward, PA Electric	FA/BA Pond 2+	0	0	+	0	0	0	NA	NA	0	0	0	+	NA	NA
	FA/BA Fill 3+	0	0	+	0	0	0	NA	NA	+	0	0	+	NA	-

Table 3.3.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. >7000 Degree Days F (+)	Ppt. ≤16" (40cm) or ≥48" (120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Shawville, PA Electric	FA Fill 3+	0	0	+	0	0	0	+	NA	+	0	0	+	NA	-
	BA Pond 2+	0	0	+	0	0	0	+	NA	0	0	0	+	NA	-
Sunbury, PA P&L	FA Pond 1+	0	0	0	0	0	0	-	NA	0	0	0	+	+	NA
	BA Pond +	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	-
Bull Run, TVA	FA/BA Pond 2+	0	+	0	0	0	0	NA	NA	0	0	0	+	NA	NA
Kingston, TVA	FA/BA Pond 1+	0	+	0	0	0	0	NA	NA	0	0	0	++	0	--
Sevier, TVA	FA/BA Pond *	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	-
Watts Bar, TVA	FA/BA Pond 2+	0	+	0	0	0	0	NA	NA	0	0	0	+	NA	NA
Clinch River, Appalachian Power	FA/BA Fill *	0	0	0	0	0	0	-	NA	+	0	0	+	NA	-
	BA Pond *	0	0	0	0	0	0	-	NA	0	0	0	+	+	-
Glen Lyn, Appalachian Power	FA Pond 3+	0	0	0	0	0	0	NA	+	0	0	0	+	+	NA
	FA/BA Fill 1+	0	0	0	0	0	0	NA	NA	+	0	0	+	NA	-
	BA Pond 1+	0	0	0	0	0	0	NA	+	0	0	0	NA	+	-
Albright, Monongahela Power	NA 3+	0	+	+	0	0	0	NA	NA	NA	NA	NA	+	NA	NA

Table 3.3.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. ≥7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Amos, Appalachian Power	FA Pond 2+	0	0	0	0	0	0	+	NA	0	0	0	NA	+	NA
	FA/BA Fill *	0	0	0	0	0	0	-	NA	+	0	0	+	NA	-
	BA Pond 1+	0	0	0	0	0	0	+	NA	0	0	0	NA	NA	-
Fort Martin, Monog. Power	NA 2+	0	0	+	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Harrison, Monog. Power	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Kammer, OH Power	BA Fill 1+	NA	NA	NA	0	0	0	NA	NA	+	NA	0	NA	NA	NA
	BA Pond 1+	0	0	0	0	0	0	NA	NA	NA	0	0	+	NA	NA
Kanawha River, App. Power	FA Fill 2+	0	0	0	0	0	0	NA	NA	+	0	0	NA	+	NA
	BA Pond 2+	0	0	0	0	0	0	+	NA	0	+	0	+	NA	-
Mitchell, OH Power	FA Pond 1+	0	0	0	0	0	0	+	NA	0	0	0	+	NA	-
	BA Pond *	0	0	0	0	0	0	NA	NA	0	+	0	+	NA	—
Mt. Storm, VA Electric Power	NA 1+	0	0	+	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Pleasants, Allegheny Power Systems	FA/FGD Pond 2+	0	0	0	0	0	0	NA	NA	0	0	+	NA	+	NA
Sporn, Central Operating	FA Pond 1+	0	0	0	0	0	0	+	NA	0	0	0	+	NA	-
	FA Fill 1+	0	0	0	0	0	0	-	NA	+	0	0	+	+	-
	BA Pond 3+	0	0	0	0	0	0	+	NA	0	0	0	+	+	NA

Table 3.3.5 (Continued)

		REGIONAL/GENERIC FACTORS							SITE-SPECIFIC FACTORS							
		Climate				Water Use			Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. ≥7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)		Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Willow Island, Monongahela Power	NA *	0	0	0	0	0	0		NA	NA	NA	NA	NA	NA	NA	NA

Key: NA = Information not available
0 = Not applicable
* = Sum of + and - is zero
ppt. = Precipitation
G.W. = Groundwater
S.W. = Surface water

Note: Rating methodology is described in Section 2.8; information on plants is summarized in Exhibit D.

3.3.5 Candidate and Back-up Sites

In Region B the targeted number of sites were:

- candidate sites: three,
- back-up sites: up to two.

Given the broad mix of ponding and landfill options in this region with many coal-fired power plants, the investigators attempted to recommend a mix of disposal practices.

The recommended candidate and back-up sites were:

Waste Type/Disposal Method	Candidate Sites	Back-up Sites
Coal Ash		
Fly Ash/Landfill (UL) Bottom Ash/Interim Pond (UL); Landfill (UL)	Keystone	--
Fly Ash/Pond (UL) Bottom Ash/Interim Pond (UL); sold	--	Sporn
Coal Ash and FGD		
Combined Fly & Bottom/Interim Pond (UL); Landfill (UL) (off-site) Fly/FGD (CSI) /Landfill (UL) (off-site)	Elrama	--
FGD/Pond (UL) Combined Fly & Bottom Ash/Pond (UL)	Widows Creek	--

Table 3.3.6 provides an overview on these sites' characteristics. A brief description of these sites and others follows.

Table 3.3.6

RECOMMENDED CANDIDATE AND BACK-UP SITES - APPALACHIAN REGION - REGION B

	Candidate	Description	Assessment of Disposal Operations	Geotechnical/Hydrogeologic Considerations	Other Factors
1	Keystone Pennsylvania Electric Armstrong County, PA	1872-Mw plant started up in 1967. Fly ash disposal in unlined landfill. Bottom ash disposal in interim pond and landfill.	Fly ash disposal important in future for region. Coal pile run-off to bottom ash pond.	Deep silty clay over sandstone with deep water table makes for complex flow regime. Climate permits good infiltration.	Fly ash fill in important environmental setting for impacts.
			3+	B-	4+ FA fill 3+ BA pond
2	Elrama Duquesne Light/IUCS Washington County, PA	510-Mw plant started up in 1952, (FGD in 1975). FGD wastes stabilized (CSI) and disposal is off-site. Combined fly and bottom ash disposal in interim pond and landfill.	Important stabilization process for FGD wastes. Off-site disposal provides engineering and cost baseline.	Climate permits recharge and good groundwater flow. Coal in proximity may affect flow. Underlying alluvium good monitoring medium.	Important environmental setting and potentially mitigative disposal mode
			4+	B+	6+ FA/FGD fill 3+ FA/BA pond
3	Widows Creek Tennessee Valley Authority Jackson County, AL	1977-Mw plant started up in 1952. (FGD in 1978.) FGD waste disposal in unlined pond. Combined fly and bottom ash disposal in unlined pond.	FGD ponding atypical but brackets impact.	Precipitation ample. Pond in old swamp deposits. Flow may be complex.	FGD ponding may describe important impacts; excessive precipitation plus proximity to small stream
			3 1/2+	C	5+
	Back-up				
4	Sporn Central Operating Madison County, WV	1105-Mw plant started up in 1950. Fly ash disposal in pond; bottom ash to an interim pond/sold.	Fly ash disposal mode important for region.	Climate permits only limited recharge. Fine sands under ponds over shale, sandstone or coal beds may furnish good flow for monitoring.	Fly ash ponding in this moderate climate setting.
			2 1/2+	B	1+ FA pond 3+ BA pond

Keystone, Pennsylvania Electric

Keystone of Pennsylvania Electric was designated as a candidate site. In 1979, the plant was a 12-year-old, 1872-Mw baseload plant. It is located in the central portion of Region B. Roughly 5% of the ash from this plant was sold. The plant disposed of its fly ash in an unlined landfill and it bottom ash in hydrobins followed by an interim unlined pond and an unlined landfill. The interim ponds at this site received 90% bottom ash, 5% fly ash, and 5% coal-pile runoff. The pond covered approximately 24,300 square meters (six acres) and did not have any wells. The landfill at this site covered about 336,000 square meters (83 acres) and was 260 meters (80 feet) deep. There were two wells at the landfill and data were available. The landfill received 80% fly ash and 20% bottom ash. This plant was recommended as a candidate site since it represents an important disposal mode in an apparently acceptable hydrogeologic regime and environmental setting.

Elrama, Duquesne Light and CSI

Elrama of Duquesne Light was designated as a candidate site. The Elrama plant is a 510-Mw plant and was 27 years old. It has an operational FGD system which was started up in October 1975 as of 1979. The plant disposed of its FGD waste and fly ash by the CSI process in an off-site unlined landfill 18 km (12 miles) away. Sit evaluations indicated that this is an important mode of disposal for FGD wastes in an acceptable environmental and hydrogeologic setting.

Widows Creek, Tennessee Valley Authority

Widows Creek of Tennessee Valley Authority (TVA) was designated as a candidate site. The Widows Creek plant of the TVA was a 1977-Mw plant. Widows Creek had an operational FGD system on about 550-Mw which was started up in May of 1977. The hydrogeologic data on Widows Creek was essentially incomplete. The only information available was that there is a perched water table above the pond bottom. Widows Creek disposed of FGD waste in an unlined pond and the remaining fly ash and bottom ash in a separate unlined pond, both next to a small stream with no point source discharges. This plant was recommended as a candidate site as it combines an important disposal mode and environmental setting.

Sporn, Central Operating

Sporn of Central Operating was designated as a back-up site. As of 1979, the plant was 29 years old and disposed of its fly ash and bottom ash in separate unlined ponds. The plant is located on the Ohio River. Approximately 18% of the ash generated at this plant was used, all of it bottom ash. The bottom ash pond received 100% bottom ash, covered about 60,700 square meters (15 acres) and was 6 meters (20 feet) deep. There were no wells near the bottom ash pond. The fly ash pond was 16 years old, covered 174,000 square meters (43 acres), and was 10 meters (34 feet) deep. The fly ash pond received 25% fly ash and 75% other waste, including 5% coal-pile runoff. There were no wells surrounding the fly ash pond. There were indications that there was an abandoned fly ash pond in the immediate vicinity. A new ash landfill was to become operational in late 1980. It also appeared that the ponds at this site were very close to each other. The site was rated hydrogeologically acceptable and was recommended as a back-up site for both Columbia I and Clifty Creek with respect to the separate ponding of both fly ash and bottom ash.

Some other sites considered interesting in this region (not in any special order) were:

- Cardinal, Cardinal Operating
- Gavin, Ohio Electric
- Muskingum, Ohio Power
- Homer City, Pennsylvania Electric
- Phillips, Duquesne Light
- Seward, Pennsylvania Electric
- Shawville, Pennsylvania Electric
- Kingston, Tennessee Valley Authority

  Kingston was not designated as a candidate or back-up site because further information was needed before its evaluation could be completed. However, at the time it appeared to be a potentially suitable site for study of the ponding of combined fly and bottom ash.

- Albright, Monongahela Power

Bruce Mansfield was not recommended due to its large size and because its method of FGD waste stabilization was not as likely to be practiced as processes based on fly ash and lime. Pleasants of Allegheny Power was a potential alternative if one desired to study Calcilox -based stabilization. However, the FGD system had been in operation for less than two years.

3.4 REGION C: NEW ENGLAND REGION

3.4.1 Background

The New England Region is generally bounded by the Hudson River Valley, although for purposes of this study it was extended to include New Jersey. The region includes all of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New Jersey, and a portion of eastern New York State.

As of 1977, the region had two coal-fired (greater than 80% of power generated from coal) power plants with a total capacity of 1111 Mw. Both of these plants have individual capacities of greater than 200 Mw and are considered further in this section. It is important to note that under the Power Plant and Industrial Fuel Use Act of 1978, DOE had been evaluating utility plants and, where appropriate, issuing Proposed Changeover Orders to convert to coal. This would have caused a significant shift from oil and/or gas firing to coal in this region in the next ten years. However, due to the fact that the Industrial Fuel Use Act was amended in 1981, utility coal conversions will now be undertaken on a voluntary basis only. Consequently, latest data supplied by the Department of Energy indicate: eight plants (16 units) are in the process of converting to coal and 12 plants (25 units) are likely candidates to do so. Table 3.4.1 summarizes the 1979 baseline data for these plants. The individual capacity of both of these plants was less than 700 Mw and both plants were started up* in December of 1960. Neither of these plants employed an FGD system.

This physiographic region and the prevailing climatic conditions are described in detail in Exhibit C. The average annual precipitation in this region is 102 to 115 cm (40 to 45 in.) of rainfall, and frost penetration throughout the region generally exceeds 102 cm (40 in.). Minimum average temperatures may fall well below -29°C (-20°F) and average maximum temperatures may reach 32°C (90°F). Average annual temperatures are approximately 4°C (40°F) throughout much of this region. The soils in this region are characterized by very thin residual soil covers or deposits of glacial origin of varying thickness.

3.4.2 Assessment of Disposal Operations

3.4.2.1 Categorization of Disposal Operations

Table 3.4.2 presents summary data on disposal methods in Region C. One each of the following is practiced:

- single-step landfill disposal of fly ash (at Merrimack),
- interim ponding and then sale of bottom ash (at Merrimack), and
- interim ponding followed by landfill disposal of combined fly and bottom ash (at Mercer).

---

*Date on which coal became the primary source of fuel.

Table 3.4.1

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN NEW ENGLAND REGION (C) OF THE U.S.

Plant Name	Utility Name	Capacity (Mw)[b,e] Nameplate Generating	Capacity (Mw)[b,e] FGD Scrubbed	State	County	Start-up Date Plant[c,d]	Start-up Date FGD[e]	Waste Type[f]	Disposal Method[e,f]
Merrimack*	Public Service of New Hampshire	459	--	NH	Merrimack	12/60	--	Fly Ash Bottom Ash	Landfill(CS)/sold Interim Pond(UL); sold
Mercer*	Public Service Electric & Gas	652	--	NJ	Mercer	12/60	--	Comb. Fly & Bottom	Interim Pond(UL); Landfill(off-site)

Footnotes follow Table 3.1.1.

Table 3.4.2

MATRIX OF FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS

>200 Mw IN THE NEW ENGLAND REGION (C) OF THE UNITED STATES AS OF 1979[a]

	Number of Plants		
Type of Waste	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	-	1	-
Bottom ash only	1	-	-
Combined fly and bottom ash	-	-	1
FGD waste only	-	-	-
Mixed fly ash and FGD waste	-	-	-
Mixed bottom ash and FGD waste	-	-	-
Mixed fly ash and FGD waste (stabilized)	-	-	-
Mixed fly ash, bottom ash, and FGD waste	-	-	-

---

[a] Coal-fired plants (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal.

Source: Compiled by Arthur D. Little, Inc. based on Utility Plant Data Survey Sheets used in developing reference 1.

3.4.2.2 Assessment of Disposal Operations

Table 3.4.3 presents the results of the disposal operation assessment rating for Region C. The methodology employed in making this assessment is discussed in Section 2.6. The Mercer plant appeared to be the only one warranting further evaluation from the disposal operation perspective. The Merrimack plant was eliminated from further consideration due to the fact that the majority of its ash had been sold in recent years.

3.4.2.3 Comments on Handling and Transportation of FGC Wastes

Considering the potential changeover to coal firing (from oil and gas) that is likely in this region, handling and transport of FGC wastes is likely to become important in the next ten years.

3.4.3 Geotechnical and Hydrogeologic Considerations

Table 3.4.4 provides the geotechnical ratings following the criteria system described in Section 2.7. Neither of the plants in this region were considered suitable hydrogeologically.

3.4.4 Other Site Selection Considerations

Table 3.4.5 presents the ratings for other site selection factors for the disposal operations in Region C. Discussion of the individual plants is presented in Exhibit D.

3.4.5. Candidate and Back-Up Sites

The initial targeted number of sites in this region was zero. The geotechnical ratings indicated that the plants in this region did not merit further study for purposes of this program.

3.5 REGION D: INTERIOR LOWLANDS

3.5.1 Background

The Interior Lowlands Region includes portions of western Ohio, central Tennessee, most of central Kentucky, all of Indiana, essentially all of Illinois, all of Iowa, the northern half of Missouri, and the northwestern corner of Alabama.

As of 1977, this region had 101 coal-fired (greater than 80% of power generated from coal) power plants with a total capacity of 59,209 Mw. Sixty-six of these plants with a capacity of 55,708 Mw had individual capacities of greater than 200 Mw and are considered further in this section. Table 3.5.1 summarizes the baseline data for these 66 plants. The plants in this region are generally located (a) along the Ohio River in Ohio, Kentucky, and Indiana; (b) scattered around the Indiana/Illinois border; and (c) scattered throughout central Illinois.

Table 3.4.3

ASSESSMENT OF DISPOSAL OPERATIONS IN NEW ENGLAND REGION (C) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Merrimack	X	1 1/2+	0	1+	X	Majority of ash was sold in 1978.
Mercer		1 1/2+	0	0	1 1/2+	

---

[a] Assessment rating system explained in Section 2.6.

Table 3.4.4

GEOTECHNICAL/HYDROGEOLOGIC RATING OF SITES - REGION C

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Merrimack - Public Service of New Hampshire/Merrimach County, NH, 43°08'37"N, 71°28'08"W (Concord, NH; pond for BA; LF for FA)	C	40" avg. annual precip. (gross), 8" net; avg. annual temp. = 45°F, range -20° to 90°; frost penetration = 45" per winter season. Metamorphosed LS and marbles. Thin glacial deposits; alluvium near river. Pond is 3' deep; alluvial sand under pond. Landfill is 35' thick; 6' to water; clay liner below landfill (12") over 2' fine sand/silt over 3' of gravel.	The slight net precipitation at this site does not make for copious recharge, and the very significant cross penetration should severely impede infiltration and recharge during winter months. The alluvial soils near the river at the site beneath the bottom ash pond should permit rapid flow. Beneath the alluvium is a sequence of metamorphosed limestones and marbles in which flow conditions may vary in an extremely erratic manner, making interpretation of the flow system very difficult. Beneath the landfill, the clay liner should impede leachate movement, but the underlying sands and gravels permit rapid cross flow into the bedrock system. The flow system may be very difficult to interpret.
Mercer - Public Service Electric & Gas/Mercer County, NJ, 40°37'00"N, 74°12'00"W (Pond and LF; sanitary landfill, off-site BA/FA = 5/95; Elizabeth, NJ)	C	40" avg. annual precip. (gross), 8" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 20" per winter season. Pond is 12' deep; 87 feet to water table. Triassic Sh, LS and SS; sandy, silty and clayey deposits on the Coastal Plain.	Net precipitation at this site is adequate to support infiltration, which should not be impeded by frost action. The mixed sandy, silty and clayey soil deposits beneath the disposal areas may create very irregular flow conditions, particularly since these soils are underlain by a sequence of shale, limestone and sandstone (with extreme variations in permeability among the rock units). Mixture of municipal refuse with the utility wastes in the landfill virtually precludes interpretations of data from the landfill site.

Table 3.4.5

OTHER SITE SELECTION RATINGS FOR DISPOSAL OPERATIONS IN THE NEW ENGLAND REGION (REGION C)

REGIONAL/GENERIC FACTORS — SITE-SPECIFIC FACTORS

Plant & Utility	Total Rating (+ and -)	Climate			Contaminant Migration Factor (Climate and Soils) (+)	Water Use		Setting		Mitigative Controls			Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
		Temp. >7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)		G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)			
Merrimack, Pub. Ser. Co. of New Hampshire	FA Fill 6+	+	0	+	0	0	0	+	NA	+	+	0	+	NA	NA
	BA Pond 4+	+	0	+	0	0	0	+	NA	0	0	0	+	NA	NA
Mercer, Pub. Ser. Elec. & Gas	Int. Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	NA
	FA/BA Landfill *	0	0	0	0	0	0	NA	NA	+	NA	0	NA	NA	-

Key:
NA = Information not available
0 = Not applicable
* = Sum of + and - is zero
ppt. = Precipitation
G.W. = Groundwater
S.W. = Surface water

Note: Rating methodology is described in Section 2.8; information on plants is summarized in Exhibit D.

Table 3.5.1

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN INTERIOR LOWLANDS REGION (D) OF THE U.S.

		Capacity (Mw)[b,e]				Start-up Date			
Plant Name	Utility Name	Nameplate Generating	FGD Scrubbed	State	County	Plant[c,d]	FGD[e]	Waste Type[f]	Disposal Method[e,f]
Colbert*	Tennessee Valley Auth.	1,420	--	AL	Colbert	1/55	--	Comb. Fly & Bottom	Pond(UL)
Baldwin*	Illinois Power	1,892	--	IL	Randolph	-/70	--	Comb. Fly & Bottom	Pond(UL)
Coffeen	Central Illinois Public Ser.	1,005	--	IL	Montgomery	-/65	--	NA	NA
Crawford	Commonwealth Edison	597	--	IL	Cook	-/58	--	NA	NA
Duck Creek*	Central Illinois Light	441	416	IL	Fulton	6/76	9/76	Fly/FGD Bottom Ash	Pond(UL) Pond(UL)
Edwards*	Central Illinois Light	779	--	IL	Peoria	-/60	--	Comb. Fly & Bottom	Pond(UL)
Fisk	Commonwealth Edison	546	--	IL	Cook	-/49	--	NA	NA
Hennepin*	Illinois Power	306	--	IL	Putnam	-/53	--	Comb. Fly & Bottom	Pond(UL)
Hutsonville	Central Illinois Public Ser.	200	--	IL	Crawford	-/53	--	NA	NA
Joliet*	Commonwealth Edison	1,787	--	IL	Will	-/50	--	Comb. Fly & Bottom	Pond(UL)
Kincaid*	Commonwealth Edison	1,319	--	IL	Christian	-/67	--	Fly Ash Bottom Ash	Landfill(off-site) Pond(UL)
Marion	Southern Illinois Power Coop.	283	184	IL	Williamson	8/63	5/79	Fly/FGD Bottom Ash	Landfill(?) ?
Meredosia	Central Illinois Public Ser.	564	--	IL	Morgan	-/48	--	NA	NA
Newton	Central Illinois Public Ser.	617	617	IL	Jasper	11/77	11/79	Fly/FGD(CSI) Bottom Ash	Landfill(?) ?
Powerton*	Commonwealth Edison	1,785	--	IL	Tazewell	-/72	--	Fly Ash Bottom Ash	Landfill(AL)(off-site) Hydrobin; Landfill(AL)(off-site)
Wallace*	Central Illinois Light	305	--	IL	Tazewell	-/39	--	Comb. Fly & Bottom	Pond(UL)
Waukegan	Commonwealth Edison	932	--	IL	Lake	-/52	--	NA	NA
Will County	Commonwealth Edison	1,268	167	IL	Will	-/55	2/72[h]	Fly/FGD Bottom Ash	Landfill(UL) Interim Pond(CS); Landfill(UL)
Wood River*	Illinois Power	650	--	IL	Madison	-/54	--	Comb. Fly & Bottom	Pond(UL)
Bailly*	Northern Indiana Public Ser.	615	--	IN	Porter	-/68	--	Fly Ash Bottom Ash	Interim Pond(UL); Landfill(UL) Interim Pond(UL); Landfill(UL)
Breed*	Indiana & Michigan Electric	495	--	IN	Sullivan	-/60	--	Comb. Fly & Bottom	Pond(UL)
Brown	Southern Indiana Gas & Electric	265	265	IN	Johnson	3/79	3/79	Fly/FGD Bottom Ash	Landfill(?) ?
Cayuga	Public Service Co. of Indiana	1,062	--	IN	Vermillion	-/70	--	NA	NA
Clifty Creek*	Indiana-Kentucky Electric	1,303	--	IN	Jefferson	2/55	--	Fly Ash Bottom Ash	Pond(CS) Pond(CS)
Culley*	Southern Indiana Gas & Electric	414	--	IN	Warrick	-/55	--	Comb. Fly & Bottom	Pond(UL)

Table 3.5.1 (continued)

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN INTERIOR LOWLANDS REGION (D) OF THE U.S.

Plant Name	Utility Name	Capacity (Mw)[b,e] Nameplate Generating	FGD Scrubbed	State	County	Start-up Date Plant[c,d]	FGD[e]	Waste Type[f]	Disposal Method[e,f]
Gallagher	Public Service Co. of Indiana	600	--	IN	Floyd	12/58	--	NA	NA
Gibson Station	Public Service Co. of Indiana	1,336	--	IN	Franklin	4/75	--	NA	NA
Hoosier	Hoosier Energy Div./Indiana Recreation	233	--	IN	Pike	-/68	--	NA	NA
Michigan City*	Northern Indiana Public Ser.	736	--	IN	Laporte	-/50	--	Comb. Fly & Bottom	Interim Pond(UL); Landfill(off-site)
Mitchell	Northern Indiana Public Ser.	529	115	IN	Lake	-/56	6/77	NA	NA
Petersburg	Indianapolis Power & Light	1,256	532	IN	Pike	-/67	12/77	Fly/FGD(IUCS) Bottom Ash	Landfill(UL) Landfill(UL)
Pritchard	Indianapolis Power & Light	393	--	IN	Morgan	-/51	--	NA	NA
Schahfer	Northern Indiana Public Ser.	520	--	IN	Jasper	12/76	--	NA	NA
State Line	Commonwealth Edison	963	--	IN	Lake	-/29	--	NA	NA
Stout	Indianapolis Power & Light	852	--	IN	Marion	-/58	--	NA	NA
Tanners Creek*	Indiana & Michigan Electric	1,100	--	IN	Dearborn	-/51	--	Fly Ash Bottom Ash	Pond(AL) Pond(UL)
Wabash River	Public Service Co. of Indiana	962	--	IN	Vigo	8/53	--	NA	NA
Des Moines	Iowa Power & Light	269	--	IA	Polk	3/54	--	NA	NA
George Neal*	Iowa Public Ser.	961	--	IA	Woodbury	-/64	--	Comb. Fly & Bottom	Pond(UL)
Kapp*	Interstate Power	237	--	IA	Clinton	-/47	--	Comb. Fly & Bottom	Interim Pond(UL); Landfill(off-site)/sold
Lansing*	Interstate Power	339	--	IA	Allamakee	-/48	--	Comb. Fly & Bottom	Pond(UL)
Brown*	Kentucky Utilities	739	--	KY	Mercer	-/57	--	Comb. Fly & Bottom	Pond(UL)
Cane Run*	Louisville Gas & Electric	1,016	666	KY	Jefferson	-/54	8/76	Fly/Bottom/FGD	Interim Pond(CS); Landfill(AL)
Coleman	Big Rivers Rural Electric Coop.	521	--	KY	Hancock	9/69	--	NA	NA
Cooper	East Kentucky Rural Electric Coop.	320	--	KY	Pulaski	2/65	--	NA	NA
Ghent*	Kentucky Utilities	1,113	--	KY	Carroll	4/74	--	Comb. Fly & Bottom	Pond(UL)
Green River*	Kentucky Utilities	263	64	KY	Muhlenberg	-/50	6/76	Fly/FGD Comb. Fly & Bottom	Pond(UL) Pond(UL)
Mill Creek*	Louisville Gas & Electric	711	442	KY	Jefferson	-/72	3/79	Fly/Bottom/FGD	Pond(CS)
Paddys Run*	Louisville Gas & Electric	337	72	KY	Jefferson	-/42	4/73	Fly/FGD Comb. Fly & Bottom	Landfill(CS) Pond(CS)
Paradise*	Tennessee Valley Auth.	2,558	--	KY	Muhlenberg	5/63	--	Fly Ash Bottom Ash	Pond(UL) Interim Pond(UL); Landfill(mine)

Table 3.5.1 (concluded)

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN INTERIOR LOWLANDS REGION (D) OF THE U.S.

Plant Name	Utility Name	Capacity (Mw)[b,e] Nameplate Generating	Capacity (Mw)[b,e] FGD Scrubbed	State	County	Start-up Date Plant[c,d]	Start-up Date FGD[e]	Waste Type[f]	Disposal Method[e,f]
Reid	Big Rivers Rural Electric Coop.	430	--	KY	Henderson	1/66	--	NA	NA
Smith*	Owensboro Municipal Utilities	416	--	KY	Daviess	4/64	--	Comb. Fly & Bottom Fly Ash Bottom Ash	Pond(UL) Landfill(mine) Interim Pond(UL); Landfill(mine)
Spurlock	East Kentucky Rural Electric Coop.	300	--	KY	Mason	9/77	--	NA	NA
Labadie*	Union Electric	2,482	--	MO	Franklin	-/70	--	Comb. Fly & Bottom	Pond(UL)
Sibley	Missouri Public Ser.	523	--	MO	Jackson	-/60	--	NA	NA
Sioux*	Union Electric	1,099	--	MO	St. Charles	-/67	--	Comb. Fly & Bottom	Pond(UL)
Thomas Hill	Associated Electric Coop.	470	--	MO	Randolph	11/66	--	NA	NA
Acme*	Toledo Edison	307	--	OH	Lucas	-/41	--	Fly Ash Bottom Ash	Pond(UL) Landfill(off-site)
Bay Shore*	Toledo Edison	639	--	OH	Lucas	-/55	--	Comb. Fly & Bottom	Pond(UL)
Beckjord*	Cincinnati Gas & Electric	1,221	--	OH	Clermont	6/52	--	Fly Ash Comb. Fly & Bottom	Landfill(UL) Interim Pond(UL); Landfill(UL)
Hutchings	Dayton Power & Light	414	--	OH	Montgomery	7/48	--	NA	NA
Miami Fort*	Cincinnati Gas & Electric	950	--	OH	Hamilton	12/49	--	Fly Ash Comb. Fly & Bottom	Landfill(UL) Interim Pond(UL); Landfill(UL)
Stuart	Dayton Power & Light	2,440	--	OH	Adams	8/70	--	NA	NA
Tait	Dayton Power & Light	448	--	OH	Montgomery	6/56	--	NA	NA
Cumberland*	Tennessee Valley Auth.	2,600	--	TN	Stewart	3/73	--	Comb. Fly & Bottom	Pond(UL)/sold
Gallatin*	Tennessee Valley Auth.	1,255	--	TN	Sumner	11/56	--	Comb. Fly & Bottom	Pond(UL)/sold

---

Footnotes follow Table 3.1.1.

CSI = Conversion Systems, Inc.

Plant generating capacities ranged from a low of 200 Mw to a high of 2600 Mw. Forty-five of the plants fell in the 200 to 1000 Mw range, while the other 21 plants were greater than 1000 Mw. As of 1979, ten plants had start-up* dates of less than 10 years prior; 46 of the plants had start-up dates from 10 to 30 years prior; and ten had start-up dates of more than 30 years prior. As of 1979, there were 11 FGD systems (10 currently operational) in this region. Nine of these had been started up within the last five years and two were started up in the early 1970's.

This physiographic region and the prevailing climatic conditions are described in detail in Exhibit C. The average annual temperatures in this region range from about 7 to 13°C (45 to 55°F). Temperatures vary from a maximum of about 38°C (100°F) to a minimum of about -18°C (-1°F) in southern Kentucky to -32°C (-26°F) in northern Iowa. Precipitation generally increases in a southeasterly direction from an average value of approximately 64 cm (25 in.) in northwestern Iowa to approximately 115 cm (45 in.) in central Kentucky. Frost penetration increases from approximately 46 cm (18 in.) in central Kentucky to as much as 150 cm (60 in.) in the extreme northern portions of Ohio, Illinois, and Iowa. For the most part, this region is overlain with thick residual soils and deposits of thick alluvium in those portions of the region which have not been glaciated. Thick deposits of glacial alluvium also exist along streams in this region. Glacial deposits vary from sandy outwash materials to silty clay moraines and ground tills.

3.5.2 Assessment of Disposal Operations

3.5.2.1 Categorization of Disposal Operations

Table 3.5.2 presents summary data on disposal methods in Region D. The utility operations of the Interior Lowlands typically employ one or more of five basic disposal practices for fly ash, bottom ash, and FGD wastes:

- single-step pond disposal for combined fly and bottom ash,
- single-step landfill disposal for fly ash,
- single-step landfill disposal for fly ash co-disposed with FGD waste,
- single-step pond disposal for fly ash co-disposed with FGD waste, and
- single-step landfill disposal for stabilized fly ash/FGD wastes.

---

*Date on which coal became the primary source of fuel.

Table 3.5.2

MATRIX OF FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS > 200 Mw IN THE INTERIOR LOWLANDS REGION (D) OF THE UNITED STATES[a]

Type of Waste	Number of Plants		
	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	4	5	1
Bottom ash only	4	3	4
Combined fly and bottom ash	21	-	4
FGD waste only	-	-	-
Mixed fly ash and FGD waste	2	4	-
Mixed bottom ash and FGD waste	-	-	-
Mixed fly ash and FGD waste (stabilized)	-	2	-
Mixed fly ash, bottom ash, and FGD waste	1	-	1

---

[a] Coal-fired plants (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal.

Source: Compiled by Arthur D. Little, Inc. based on Actual Utility Plant Data Survey Sheets used in developing the report(1).

Combined fly and bottom ash disposal in unlined ponds was practiced at 21 plants in this region on which data was available. Five plants practiced the single-step landfilling of fly ash. Eleven plants in this region employed FGD systems, of which ten were operational. The FGD system at Will County (Commonwealth Edison) was no longer operational. Out of the 11 plants with FGD systems, disposal information was available on 10. Four plants landfilled the FGD waste co-disposed with fly ash. Two plants co-disposed fly ash and FGD waste in unlined ponds. Two plants employed the CSI stabilization process and landfilled the resultant fly ash/FGD waste mixture. Two plants ponded mixtures of fly and bottom ash co-disposed with FGD waste and one of these two then landfilled the dewatered ponded material. There was no information available on the disposal operations of 26 of the plants. A general overview of each of the major types of disposal practiced in this region is presented below.

Disposal of Fly Ash and Bottom Ash in Ponds

A variety of ponding operations are practiced in Region D. The most prevalent, however, was the disposal of combined fly and bottom ash in unlined ponds.

- Combined fly and bottom ash ponding was practices at Colbert, Baldwin, Edwards, Hennepin, Joliet, Wallace, Wood River, Breed*, Culley, George Neal, Lansing, Brown, Ghent, Green River, Paddys Run, Smith, Labadie, Sioux, Bay Shore, Cumberland, and Gallatin.
- The separate ponding of fly ash was practiced at Tanners Creek, Paradise, Clifty Creek, and Acme.
- Bottom ash ponding was practiced at Tanners Creek, Duck Creek, Kincaid, and Clifty Creek.
- Ponding of fly ash/FGD waste was practiced at Duck Creek and Green River.
- Ponding of fly ash/bottom ash/FGD waste was practiced at Mill Creek. A contract to employ the CSI process at Mill Creek was announced in 1979 (22).

Disposal of Fly Ash, Bottom Ash, and FGD Wastes in Landfills

A variety of landfilling operations are practiced in Region D. The most prevalent, however, was the landfilling of fly ash alone. In addition, landfilling of both stabilized and unstabilized FGD wastes was practiced.

---

*As noted in Table 3.5.3, the Breed plant was scheduled to be converted to landfill disposal of fly ash in 1979.

- Fly ash landfilling was practiced at Kincaid, Powerton, Smith (mine), Beckjord, and Miami Fort.

- Bottom ash landfilling was practiced at Powerton, Petersburg, and Acme.

- Mixed fly ash/FGD waste landfilling was practiced at Marion, Will County, Brown, and Paddys Run. In addition, Newton and Petersburg practiced landfilling of CSI stabilized fly ash/FGD waste.

Disposal of Fly Ash, Bottom Ash, and FGD Wastes in Interim Ponds/Landfills

Various interim ponding/landfill operations are practiced in Region D. The two most prevalent were the interim ponding/landfilling of combined fly ash and bottom ash and of bottom ash alone. In addition, one plant practiced this type of disposal for mixtures of fly ash/bottom ash/FGD waste.

- Fly ash disposal by interim pond/landfill was practiced at Bailly.

- Bottom ash disposal by interim pond/landfill was practiced at Will County, Bailly , Paradise (mine), and Smith (mine).

- Combined fly and bottom ash disposal by interim pond/landfill was practiced at Michigan City, Kapp, Beckjord, and Miami Fort.

- Fly ash/bottom ash/FGD waste disposal by interim pond/landfill was practiced at Cane Run.

- A contract to employ the CSI process at Cane Run was announced in 1979 (22).

3.5.2.2 Assessment of Disposal Operations

Table 3.5.3 presents the results of the disposal operation assessment rating for Region D. The methodology employed in making this assessment is discussed in Section 2.6. At least 15 plants appeared to warrant further evaluation from the disposal operation perspective. Hydrogeologic and other site selection ratings narrowed the choice considerably.

Seven plants (Breed, Petersburg, Tanners Creek, Cane Run, Mill Creek, Cumberland, and Gallatin) were eliminated from further consideration due to the disposal site being less than two years old, or the fact that the majority of the plant's ash had been sold in recent years.

Table 3.5.3

ASSESSMENT OF DISPOSAL OPERATIONS IN INTERIOR LOWLANDS REGION (D) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Colbert		1 1/2+	1+	0	2 1/2+	
Baldwin		1 1/2+	1+	0	2 1/2+	Plant intends to route water treatment wastes to ash ponds.
Coffeen		1 1/2+	NA	NA	NA	
Crawford		1/2+	NA	NA	NA	
Duck Creek		1 1/2+	1+	1/2+	3+	Fly and FGD co-disposed in pond.
Edwards		1 1/2+	1+	0	2 1/2+	Fly ash collected dry and ponded with bottom ash.
Fisk		1/2+	NA	NA	NA	
Hennepin		1 1/2+	1+	0	2 1/2+	Extraneous pond influents are primarily due to demineralizer wastes and plant building sumps.
Hutsonville		0	NA	NA	NA	
Joliet		1 1/2+	1+	0	2 1/2+	Plant intends to go to dry fly ash handling. Pond is a quarry.
Kincaid		1 1/2+	0	1/2+	2+	
Marion		0	1+	NA	NA	FGD system is < 2 years old.
Meredosia		0	NA	NA	NA	
Newton		1+	1+	1/2+	2 1/2+	FGD system is < 2 years old. Employs IUCS stabilization process.
Powerton		1 1/2+	0	1+	2 1/2+	FGD system under construction. Will employ IUCS stabilization process. Extraneous pond influents are primarily due to plant building sumps. Landfill is lined with Poz-O-Pac.
Wallace		0	1+	0	1+	
Waukegan		1 1/2+	NA	0	NA	
Will County		1 1/2+	2+	1/2+	4+	FGD system is no longer operational. Plant employs a wet particulate scrubber.
Wood River		1 1/2+	1+	0	2 1/2+	Extraneous pond influents are primarily due to water treatment wastes and metal cleaning wastes.
Bailly		1 1/2+	0	0	1 1/2+	Plant intends to go to dry fly ash handling to a landfill.
Breed	X	1 1/2+	1+	0	X	Plant used 96% of ash in 1978. Plant intends to go to dry fly ash handling to a landfill.

Table 3.5.3 (continued)

ASSESSMENT OF DISPOSAL OPERATIONS IN INTERIOR LOWLANDS REGION (D) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Brown		0	1+	1/2+	1 1/2+	FGD system is < 2 years old.
Cayuga		1 1/2+	NA	0	NA	
Clifty Creek		1 1/2+	0	1/2+	2+	Separate fly ash and bottom ash ponds.
Culley		1 1/2+	1+	1/2+	3+	Six-year old pond has reached its design life. Other pond is < 2 years old.
Gallagher		1 1/2+	NA	0	NA	
Gibson Station		1 1/2+	NA	NA	NA	
Hoosier		1/2+	NA	NA	NA	
Michigan City		1 1/2+	0	1/2+	2+	
Mitchell		1 1/2+	1+	0	NA	FGD is a recovery process.
Petersburg	X	1 1/2+	2+	1/2+	X	Landfill is < 2 years old. Employs IUCS stabilization process as of 10/78.
Pritchard		1/2+	NA	0	NA	
Schahfer		1 1/2+	NA	NA	NA	
State Line		1 1/2+	NA	0	NA	
Stout		1 1/2+	NA	NA	NA	
Tanners Creek	X	1 1/2+	0	1/2+	X	Pond is < 2 years old. Fly ash pond is lined with PVC.
Wabash River		1 1/2+	NA	0	NA	
Des Moines		1/2+	NA	0	NA	
George Neal		1 1/2+	1+	0	2 1/2+	
Kapp		1 1/2+	0	0	1 1/2+	
Lansing		1 1/2+	1+	0	2 1/2+	Pond is 2 1/2 years old.
Brown		1+	1+	0	2+	Extraneous pond influents classified as service water.
Cane Run	X	1 1/2+	1+	1+	X	Landfill is < 2 years old. Plant intends to go to IUCS stabilization process. Landfill is lined with Poz-O-Pac.
Coleman		1 1/2+	NA	0	NA	
Cooper		0	NA	NA	NA	
Ghent		1 1/2+	1+	0	2 1/2+	Extraneous pond influents include cooling tower blowdown and plant service water.
Green River		0	2+	1/2+	2 1/2+	Fly ash and FGD ponded. Pond is 4 years old.

Table 3.5.3 (concluded)

ASSESSMENT OF DISPOSAL OPERATIONS IN INTERIOR LOWLANDS REGION (D) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Mill Creek	X	1 1/2+	0	1+	X	FGD system is < 2 years old. Plant intends to go to IUCS stabilization process.
Paddys Run		0	2+	1+	3+	Extraneous pond influent primarily due to coal pile run-off. Fly ash and FGD is landfilled.
Paradise		1 1/2+	0	0	1 1/2+	
Reid		1/2+	NA	0	NA	FGD system operational as of 12/79. Employs IUCS stabilization process.
Smith		1 1/2+	1+	1/2+	3+	Landfill is a mine.
Spurlock		1/2+	NA	NA	NA	
Labadie		1 1/2+	1+	0	2 1/2+	Extraneous pond influents include coal pile run-off and boiler blowdown.
Sibley		1 1/2+	NA	0	NA	
Sioux		1 1/2+	1+	0	2 1/2+	Extraneous pond influents include coal pile run-off and boiler blowdown.
Thomas Hill		1/2+	NA	0	NA	
Acme		1+	0	1/2+	1 1/2+	
Bay Shore		1 1/2+	1+	0	2 1/2+	Pond is 4 years old.
Beckjord		1 1/2+	0	1/2+	2+	
Hutchings		1/2+	NA	NA	NA	
Miami Fort		1 1/2+	0	1/2+	2+	Extraneous pond influent is coal pile run-off.
Stuart		1 1/2+	NA	NA	NA	
Tait		1/2+	NA	NA	NA	
Cumberland	X	1 1/2+	1+	0	X	All ash was sold or used by TVA in 1978.
Gallatin	X	1 1/2+	1+	0	X	58% of ash was sold or used by TVA in 1978.

---

[a] Assessment rating system explained in Section 2.6.

3.5.2.3 Comments on Handling and Transportation of FGC Wastes

This region had a number of plants generating FGC wastes. The handling and transportation systems employed follow conventional practice and disposal is usually on-site. Both fly ash and bottom ash are normally wet sluiced (see Table 2.4.4).

3.5.3 Geotechnical and Hydrogeologic Considerations

Table 3.5.4 presents an evaluation of geotechnical and hydrogeologic considerations and subsequent ratings for the sites in Region D. The methodology employed in making this assessment is presented in Section 2.7.

3.5.4 Other Site Selection Considerations

3.5.4.1 Discussion

In the Interior Lowlands Region, the northern portions of the region experience temperature extremes. Sixteen out of the 66 sites in the region have greater than 7000 degree days per year. Only four of the sites receive greater than 120 cm (48 in.) of precipitation per year (gross) and none receive less than 40 cm (16 in.). Two plants on the western edge of the region experience fewer than 150 frost-free days per year. None of the region combines excessive precipitation with pervious coastal-type soils.

The Second National Water Assessment (21) indicated that there is significant potential for groundwater overdraft in the areas of about 10 of the sites while surface water shortage was reported to be a critical factor in only one area.

3.5.4.2 Ratings

Table 3.5.5 presents the ratings for other site selection factors for the plants in Region D. Narrative discussion on the plants is in Exhibit D.

3.5.5. Candidate and Back-Up Sites

In Region D the targeted numbers of sites were:

- candidate sites: up to three;
- back-up sites: up to three.

Table 3.5.4

GEOTECHNICAL/HYDROGEOLOGIC RATING OF SITES - REGION D

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Colbert - TVA/Colbert County, AL, 34°-44'-13" N, 87°-51'-05" W (on Tennessee River)	C+	52" avg. annual precip. (gross), 12" net; avg. annual temp. ≈ 62°F, range 10° to 100°; frost penetration ≐ 5"± max. 9' lean clay beneath ash pond; near Regions A1 and B. Upper Paleozoic (Miss.) LS, SS, Sh sedimentaries with overlying alluvial sediments. Silty, clayey soils over sedimentary rocks; residual clayey soils over Paleozoic rocks.	Negligible, short-lived frost penetration would not impede infiltration produced by the high net precipitation at this site; groundwater flow locally should be ample. Silty, clayey soils over mixed sedimentary bedrocks (limestone, sandstone and shale) make for a very complex flow system, very difficult to evaluate.
Baldwin - Illinois Power/ Randolph County, IL 38°-11'-30" N, 89°-52'-35" W (25 miles SE of St. Louis)	B+	38" avg. annual precip. (gross), 0"-5" net; avg. annual temp. = 54°F, range -10° to 100°; frost penetration = 18"-20" avg. Modern sandy alluvium over silty glacial till, with some glacial outwash deposits of sand and gravel. Pennsylvanian bedrock (Carbondale) SS, Sh, coal. 5'-7' of loess cover in some areas.	Low net precipitation but only moderate frost action together should make for limited infiltration and local recharge to the groundwater flow system. The subsoils at the site immediately below the disposal areas appear to be pervious sandy materials underlain by an impervious glacial deposit over mixed sandstone, shale and coal. The limited local recharge at the site makes this a less than ideal situation for monitoring, although the bedrock and subsoil conditions are favorable.
Coffern		Inadequate data for geotechnical evaluation.	
Crawford		Inadequate data for geotechnical evaluation.	
Duck Creek - Central Illinois Light/Canton, IL	B-	40" avg. annual precip. (gross), 0"-5" net; avg. annual temp. ≐ 53°F, range -10° to 100°; frost penetration = 18"-20" avg. Carbondale formation of SS, Sh, coal, some Ls, covered with silty till, sand and gravel lenses, in some areas.	Only moderate frost penetration should not impede infiltration and recharge at this site although local recharge is limited by the low net precipitation in the area. The mixed silty till soils containing sand and gravel lenses above a sequence of sandstone, shale, coal and limestone may create a complex flow system, difficult to evaluate.
Edwards - Central Illinois Light/Peoria County, IL,	B	40" avg. annual precip. (gross), 0"-5" net; avg. annual temp. ≐ 52°F, range -10° to 100°; frost penetration ≐ 20" avg. Modesto formation of Pennsylvanian SS, Sh, coal, some limestone. Gray compact silty till with some gravel, sand and silt inclusions. 15' of loess in some places.	Only slight net precipitation should make for only limited local recharge to the groundwater flow system; moderate frost action should limit infiltration only slightly during the winter months. The combination of relatively impervious glacial soils with gravel, sand and silt inclusions may be difficult to monitor and evaluate. The flow system at this site may be complicated; site-specific data are needed for a final evaluation.

Table 3.5.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Fisk		Inadequate data for geotechnical evaluation.	
Hennepin - Illinois Power/ Putnam County, IL, 41°-18'-0" N, 89°-19'-29" W	A-	38" avg. annual precip. (gross), 0"-5" net; avg. a-nual temp. = 50°F, range -15° to 95°; frost penetration = 20"-22" avg. Quaternary alluvium of sands, silts and clay along modern streams with some glacial outwash of sand and gravel, over Pennsylvanian sandstones, shales and coal. 10' of loess in areas away from the river.	Alluvial soils mixed with glacial alluvium of sand and gravel beneath this site should furnish a pervious flow medium relatively easy to monitor and evaluate. Low net precipitation may limit local recharge to the groundwater system but groundwater supplies should be ample in the area because of the location of the plant near a large stream in pervious materials.
Hutsonville		Inadequate data for geotechnical evaluation.	
Joliet - Commonwealth Edison/ Will County, IL	C	35" avg. annual precip. (gross), -10" net; avg. annual temp. ± 48°F, range -15° to 95°; frost penetration = 30" avg. Silurian limestone bedrock overlain by glacial lake bed deposits (clayey) and silty clay moraine deposits. Disposal area is in a limestone quarry. The quarry is a very poor location for monitoring.	The surficial soils near the plant site consist of almost impervious clayey lake bed soils and moraine deposits. The location of the area for utility wastes in a limestone quarry creates a groundwater flow situation virtually impossible to monitor.
Kincaid - Commonwealth Edison/ Christian County, IL (10 miles SE of Springfield - near lake)	B-	36" avg. annual precip. (gross), -10" net; avg. annual temp. ± 52°F, range -10° to 100°; frost penetration = 20"-25" avg. Pleistocene Illinoian till, compact hard silty, sandy and clayey till and intercalated sand and gravel. Pennsylvanian bedrock of limestones and coal with some sandstones. 10' of loess in some places.	Net evaporation and significant frost penetration should constrain infiltration and local groundwater recharge. A sequence of till layers interbedded with sand and gravel lenses over a bedrock sequence of limestones, coal and sandstones may create a flow system very difficult to interpret. Overlying layers of loess also may interfere with monitoring and evaluation activities.
Marion		Inadequate data for geotechnical evaluation.	
Meredosia		Inadequate data for geotechnical evaluation.	

Table 3.5.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Newton		Inadequate data for geotechnical evaluation.	
Powerton - Commonwealth Edison/ Tazewell County, IL (in Pekin)	B-	40" avg. annual precip. (gross), -2" net; avg. annual temp. ≐ 53°F, range -10° to 100°; frost penetration ≐ 20" avg. Well-sorted glacial outwash sand and gravel. Poz-o-pac 8' liner. Five monitoring wells. Pennsylvanian SS, Sh, coal, some LS bedrock.	Net evaporation and moderate frost penetration should limit infiltration and local groundwater recharge, particularly during winter months. The presence of an 8' thick liner below the disposal area should severely limit migration of liquids out of the disposal area, and may effectively preclude measurement of contamination in the underlying sand and gravel soils. This site could furnish an opportunity to measure the effectiveness of a Poz-o-pac liner.
Wallace - Central Illinois Light/Tazewell County, IL, 40°-41'-08" N, 89°-34'-48" W (across river from Peoria)	B+	40" avg. annual precip. (gross), 0"-5" net; avg. annual temp. ≐ 52°F, range -10° to 100°; frost penetration = 20" avg. Modern stream alluvium of sands, silts, some clays, some glacial outwash. Pennsylvanian, Carbondale and Modesto SS, Sh, coal, and some LS. In some places, 15' of loess cover. Old plant; maybe complex site changes.	Low net precipitation but only moderate frost action should produce limited infiltration and limited local groundwater recharge. The alluvial sands, silts and clays mixed with outwash below the site should provide a flow medium amenable to monitoring, although cross flow with the underlying sandstones, shales, coal and limestone may present difficulties in interpretation of monitoring results.
Waukegan		Inadequate data for geotechnical evaluation.	
Will County		Inadequate data for geotechnical evaluation.	
Wood River - Illinois Power/ Madison County, IL, 38°-52'-14" N, 90°-08'-25" W (near mouth of Missouri, on Mississippi River, 5 miles north of St. Louis, south of Alton)	A-	38" avg. annual precip. (gross), 0"-5" net; avg. annual temp. ≐ 54°F, range -5° to 95°; frost penetration ≐ 18"-20" avg. 20" avg. annual snow. Sand and gravel glacial outwash in former valley; poorly sorted sand, silt and clay along modern streams; Mississippian SS, Sh, and LS over Pennsylvanian, Carbondate (SS, Sh, coal, with LS). 15' of loess cover in some areas.	The sand and gravel glacial outwash below this plant site mixed with modern alluvial soils should provide a good medium for groundwater flow monitoring. A slight possibility of cross flow with underlying bedrock in it exists, but the position of the plant near the Mississippi River should guarantee ample groundwater flow in the pervious soils below the plant site.

Table 3.5.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Bailly - Northern Indiana Public Service/Porter County, IN, 41°-38'-15" N, 87°-06'-15" W (5 miles from Lake Michigan)	B	34" avg. annual precip. (gross), -8" net; avg. annual temp. = 49°F, range -15° to 95°; frost penetration 35" avg. Wisconsinan glacial moraines and kames. 12" slag over 10' of sand, under pond. Some old wells of undetermined depth. Very high water table. Niagaran LS bedrock (Silurian) at depth.	The net evaporation at this site may limit the total infiltration and local recharge of groundwater reserves, and frost action will impede infiltration during winter months. The high water table at the site reflects the influence of the regional flow system. The presence of pervious sand under the disposal areas should provide an opportunity for evaluation, although the use of slag beneath the disposal pond may influence leachate and groundwater movement and quality.
Breed - Indiana and Michigan Electric/Sullivan County, IN, 39°-13'-15" N, 87°-35'-40" W (15 miles SW of Terre Haute, on Wabash River)	B	40" avg. annual precip. (gross), 2" net; avg. annual temp. = 55°F, range -5° to 100°; frost penetration = 20" avg. 10'± silty clay under pond and landfill. Pennsylvanian Sh, SS, coal with some LS. Wabash River alluvium. Water table at 10'.	The silty clay subsoils beneath the pond and landfill for this plant may make groundwater and leachate flow very slow and difficult to monitor. Only moderate frost penetration should not seriously impede infiltration, but infiltration may be slight because of the low net precipitation at the site. There is some possibility for cross flow with bedrock layers which contain coal and which could affect the groundwater quality.
Brown - Southern Indiana Gas & Electric		Inadequate data for geotechnical evaluation.	
Cayuga		Inadequate data for geotechnical evaluation.	
Clifty Creek - Indiana-Kentucky Electric/Jefferson County, IN, 38°-43' N, 85°-27' W	B-	40" avg. annual precip. (gross), 2" net; avg. annual temp. = 54°F, range -5° to 95°; frost penetration = 18". Bedrock is Ordovician shales and limestones. Alluvium only near Ohio River (far from pond). 15' of brown clay over at least 5' of clay shale, below pond.	Very low net precipitation, but only moderate frost penetration, should combine to give limited infiltration and local groundwater recharge. The presence of clay and clay shale beneath the disposal pond at the site should produce very slow groundwater and leachate flow and may make sampling and monitoring of the flow system very difficult. The bedrock consisting of shales and limestones beneath the site should be relatively impervious and should contain the flow effectively.
Culley - Southern Indiana Gas and Electric/Warrick County, IN, 37°-54'-30" N, 87°-19'-30" W	B+	40" avg. annual precip. (gross), 2"-3" net; avg. annual temp. = 56°F, range 0° to 100°; frost penetration = 15" avg. Pleistocene lake bed deposits with Ohio River alluvium in some places, overlying Pennsylvanian SS, Sh and LS at depth.	Only moderate frost penetration should not seriously impede infiltration, although local groundwater recharge may be limited by low net precipitation. Groundwater flow is significantly influenced by position of the plant near the Ohio River and the location of the plant on mixed lake bed soils and river alluvium. The river alluvium should provide a good medium for flow monitoring, but the lake bed deposits should be virtually impervious.

Table 3.5.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Gallagher		Inadequate data for geotechnical evaluation.	
Gibson Station		Inadequate data for geotechnical evaluation.	
Hoosier		Inadequate data for geotechnical evaluation.	
Michigan City - Northern Indiana Public Service/ Laporte County, IN, 41°-43'-01" N, 86°-54'-55" W Michigan City)	B+	34" avg. annual precip. (gross), -8" net; avg. annual temp. = 48°F. Pleistocene lake sands and other lake deposits including clays. Silurian LS bedrock at great depth. 8' to water table. 12" fine slag, over 12" coarse slag, over 6' of sand, below pond. Water table above surface in spots.	Net evaporation at this site may limit infiltration to only certain periods of the year and thus may limit a local groundwater recharge. A regional flow system may predominate. The subsoils at the site consist of lake sands and other deposits including clays with limestone bedrock at great depth. This system may be amenable to monitoring and evaluation efforts. The presence of 60 centimeters of slag below the disposal pond may complicate the flow system physically and chemically.
Mitchell		Inadequate data for geotechnical evaluation.	
Petersburg - Indianapolis Power & Light / Pike County, IN (in Petersburg)	C	44" avg. annual precip. (gross), 0"-5" net; avg. annual temp. = 55°F, range -5° to 100°. Pennsylvanian SS, LS and coal, some Sh. Possibly some alluvium. Start-up in 1976.	Below net precipitation but only frost action should make for limited infiltration and local groundwater recharge during certain periods of the year. Residual soils and possibly some alluvial soils over sandstone, limestone, and coal bedrock may make for a very complex flow system. Additional data are required for a final evaluation.
Pritchard		Inadequate data for geotechnical evaluation.	

Table 3.5.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Schahfer		Inadequate data for geotechnical evaluation.	
State Line		Inadequate data for geotechnical evaluation.	
Stout		Inadequate data for geotechnical evaluation.	
Tanners Creek - Indiana and Michigan Electric/ Dearborn County, IN, 39°-05' N, 84°-51'-30" W (SW of Cincinnati, on Ohio River)	B-	40" avg. annual precip. (gross), 4" net; avg. annual temp. = 55°F, range -5° to 95°; frost penetration = 18" avg. 20 mil PVC liner over 2' clay liner, over 3' fine sand, below FA pond. Water table at 3'. Three monitoring wells, but pond is only one year old. Glacial outwash sands and gravels along Ohio River over Ordovician LS and Sh bedrock.	The sandy soils beneath the disposal areas at this site should provide a good medium for flow monitoring, although the possibility exists for a cross flow with underlying limestone bedrock units. The use of a clay liner beneath an artificial liner should severely constrain leachate flow at the site and may frustrate monitoring efforts although the site provides an opportunity to test the effectiveness of such liners. The newness of the disposal operation may cause questions concerning the significance of the test results.
Wabash River		Inadequate data for geotechnical evaluation.	
Des Moines		Inadequate data for geotechnical evaluation.	
George Neal - Iowa Public Service/Woodbury County, IO (BA/FA pond, four monitoring wells, 25' deep)	B	26" avg. annual precip. (gross), -15" net; avg. annual temp. $\approx$ 50°F, range -20° to 100°; frost penetration = 30" per winter season. Late Mesozoic Cretaceous sedimentary bedrock, overlain with loess. May be alluvium present if near Missouri River. Pond depth is 15'; 25' to water table.	Significant net evaporation and moderate frost action should limit local groundwater recharge at this site. Alluvial subsoils with a water table approximately three meters below the bottom of the disposal pond and the existence of four monitoring wells already in place at the disposal site, create a situation which may be easily understood, although more site-specific data are required for a final evaluation and rating.

Table 3.54 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Kapp - Interstate Power/Clinton County, IA, 41°-48'-29" N, 90°-14'-00" W (City of Clinton) (BA/FA pond; landfill after settling)	C	35.8" avg. annual precip. (gross), 2"± net; avg. annual temp. ≈ 50°F, range -20° to 100°; frost penetration = 30" per winter season. Pond is 11' deep; est. water table at 6'-10'. Bedrock is upper Paleozoic continental sedimentaries; loess cover over bedrock and Mississippi River alluvium near stream.	Significant frost penetration should limit infiltration and local recharge during winter months and low net precipitation may produce only limited quantities of recharge. A sequence of loess soils over residual soils over sedimentary bedrock with some alluvium near the Mississippi River makes for a complex flow system and the age of the disposal operation further complicates analysis of the flow patterns at the site. The interim nature of the ponding operation also complicates the analysis.
Lansing - Interstate Power/ Allamakee County, IA, 43°-20'-22" N, 91°-10'-28" W (City of Lansing, on Mississippi River) (BA/FA pond; 15/85)	B-	30.7" avg. annual precip. (gross), -1" net; avg. annual temp. = 45°F, range -20° to 95°; frost penetration = 40" per winter season. Bedrock is lower Paleozoic continental sedimentary rocks; loess cover over bedrock and Mississippi River alluvium near river. 4' of "probably sand" below pond. Water table at 4'; pond is 28' deep. Pond sides only lined.	Deep frost penetration and net evaporation at the site should significantly limit infiltration and local groundwater recharge. Regional groundwater flow may predominate. Mixed loess soils at upper elevations and some alluvial soils above bedrock, with a high water table and very deep disposal pond (only lined on the sides) create a complicated flow medium which may be difficult to analyze.
Brown - Kentucky Utilities/ Mercer County, KY, 37°-47'-09" N, 84°-43'-01" W (north of Danville, Kentucky River)	B-	38" avg. annual precip. (gross), 7" net; avg. annual temp. = 55"F, range -5° to 100° frost penetration = 18" avg. Ordovician limestone bedrock, some Sh, SS. Fine-grained residual soils. Possibly some thin alluvium.	Fine-grained residual soils and some thin alluvium over limestone bedrock present a relatively complicated medium for groundwater flow. Precipitation should be adequate to furnish local groundwater recharge and only moderate frost penetration should not seriously interfere with local infiltration. The possible existence of cavities in the limestone bedrock may complicate the flow pattern and the analysis of that pattern.
Cane Run - Louisville Gas and Electric/Jefferson County, KY	B-	43" avg. annual precip. (gross), '6" (?) net; avg. annual temp. = 55°F, range -5° to 100°; frost penetration = 18" avg. Glacial outwash sand and gravel over Mississippian LS bedrock (at 100' depth), with modern stream alluvium overlying. 2'-5' clay liner under pond. Poz-o-tec liner under landfill (5'). Multi-mode disposal, complex. Possibly some groundwater contamination.	The sand and gravel subsoils at this site should provide a good medium for monitoring of groundwater flow and leachate movement. The use of various liners including a clay liner under the disposal pond and a Poz-o-tec liner under the landfill may create anomalies in the flow pattern at the site since these liners are being installed for new disposal operations but were not in place for older operations at the site. Additionally, groundwater supplies in this area have been contaminated to a certain degree by industrial disposal operations in the area, and this factor may render evaluation of the flow system quality at the site very difficult.
Coleman		Inadequate data for geotechnical evaluation.	

Table 3.5A (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Cooper		Inadequate data for geotechnical evaluation.	
Ghent - Kentucky Utilities/ Carroll County, KY, 38°-45'-20" N, 85°-01'-20" W	B+	38" avg. annual precip. (gross), 6" net; avg. annual temp. = 55°F, range -5° to 100°; frost penetration = 18" avg. Ordovician limestone, SS and Sh bedrock overlain by glacial outwash and recent alluvium of sands.	Net precipitation and the seasonal character of the precipitation at this site should guarantee local recharge to the groundwater system and only moderate frost action should not seriously impede infiltration. The glacial outwash and recent alluvium below the disposal areas should provide a good medium for groundwater and leachate monitoring, although some possibility exists for cross flow between the subsoils and underlying pervious bedrock units (sandstones).
Green River - Kentucky Utilities/Muhlenburg County, KY, 37°-22'-58" N, 87°-07'-15" W (near Central City, on Green River)	C+	40" avg. annual precip. (gross), 7" net; avg. annual temp. = 55°F, range 0° to 100°; frost penetration = 18" avg. Pennsylvanian LS, SS and Sh, with coal. Green River alluvium near river. Below pond, 6" clay over 2.5' clay-shale over 1' SS to refusal.	The very thin clay and clay shale layers over pervious sandstones beneath the disposal pond at the site create a flow system condition very difficult to evaluate (the clay and clay shale, where present, would effectively prevent groundwater and leachate movement, but exposed sandstone layers would allow rapid movement of water and leachate away from the site).
Mill Creek - Louisville Gas and Electric/Jefferson County, KY	A -	43" avg. annual precip. (gross), -6" (?) net; avg. annual temp. = 55°F, range -5° to 100°; frost penetration = 18" avg. Glacial outwash sand and gravel over Mississipian LS (some Sh) bedrock (at 80' to 100' depth). Below pond, 2'-3' clay, 40'-60' to water table; below landfill, 40'-60' of sand and silt above water table, 60' sand below water table.	The glacial outwash sand and gravel over bedrock at great depth below this site should furnish a good flow medium for monitoring an evaluation. The existence of a clay liner below the disposal pond may retard leachate movement, but it also provides an opportunity to measure the effectiveness of such a liner. Additionally, the use of the Poz-o-tec liner below the new landfill to be built at this site should provide an opportunity for measuring the effectiveness of that material as a liner to prevent groundwater contamination.
Paddy's Run - Louisville Gas and Electric/Jefferson County, KY	C+	43" avg. annual precip. (gross), -6" (?) net; avg. annual temp. = 55°F, range -5° to 100°; frost penetration = 18" avg. Glacial outwash sand and gravel over Mississippian-Devonian shales and limestones (at 100'). Below pond, 2'-5' clay. Below landfill, 20' clay, over 80' sand and gravel, over rock. Water table 40'-60' below surface.	The sand and gravel subsoils below the disposal areas at this plant site should provide a good medium for monitoring an evaluation of groundwater flow and leachate movement below the disposal pond at the site. The presence of some clay soils below the pond and below the landfill may retard flow significantly. The presence of some contamination in the groundwater flow system at this site, due to industrial waste disposal activities in the area, may complicate the analysis of water quality greatly.

Table 3.5.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Paradise - TVA/Muhlenburg County, KY, 37°-15'-49" N, 86°-58'-43" W (on Green River)	B-	47" avg. annual precip. (gross), 11" net; avg. annual temp. = 55°F, range -5° to 100°; frost penetration = 18". Pennsylvanian Sh, with some SS and coal. Green River alluvium, near river. Strip mine disposal, for BA.	Precipitation at this site is more than adequate to furnish local groundwater recharge and the position of the site on the Green River, with underlying alluvial soils beneath the disposal areas, should guarantee ample groundwater flow in the vicinity of the disposal facilities. The disposal of the wastes ultimate in a strip mine area may complicate the pattern of flow around ultimate disposal area and may have confusing effects on the water and possible leachate quality.
Reid		Inadequate data for geotechnical evaluation.	
Smith - Owensboro Municipal Utilities/Daviess County, KY, 37°-47'-36" N, 87°-03'-36" W (Owensboro) (15-year-old pond probably Ohio River floodplain)	A-	46" avg. annual precip. (gross), 0" (?) net; avg. annual temp. = 55°F, range 5° to 100°; frost penetration 15" max. Interior Plateaus Region. Fine to coarse sands below pond; water table at 42' ±. Probably floodplain alluvium. Ash pond cleaned out annually. Outside landfill. Settled solids taken to strip mine. Anomaly. Pennsylvanian LS, SS, Sh at depth.	Seasonal precipitation with very low net annual precipitation should create only limited local infiltration and recharge at this site. A regional groundwater flow system with connections to the Ohio River should predominate. The subsoils below the pond consist of alluvial sands and should provide a good medium for groundwater monitoring and analysis. Annual dredging of the ash pond and disposal of solids at a distant site limit the effectiveness of monitoring at this site.
Spurlock		Inadequate data for geotechnical evaluation.	
Labadie - Union Electric/ Franklin County, MO (30 miles west of St. Louis, 5 miles south of Missouri River, in Labadie)	B+	36" avg. annual precip. (gross), -5"± net; avg. annual temp. = -5°F, range -5° to 100°; frost penetration = 20" avg. Bedrock is Ordovician limestones and sandstones; clay and sandy clay residual soils. Possibly Missouri River floodplain alluvium.	Net evaporation and the seasonal character of precipitation at this site, together with only moderate frost penetration, should produce only limited local infiltration and local recharge of the groundwater flow system. A sequence of clay residual soils, some Missouri River alluvium, and limestone bedrock may furnish a flow medium amenable to sampling and analysis, although the sequence of clay soils may inhibit the flow locally.
Sibley		Inadequate data for geotechnical evaluation.	

Table 3.5.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Sioux - Union Electric/ St. Charles County, MO	B	36" avg. annual precip. (gross), -5"± net; avg. annual temp. = 55°F, range -5° to 100°; frost penetration = 20" avg. Plant is just north of Missouri River. Mississippian or Ordovician sedimentary bedrock, principally limestones, some shales and sandstones. Fine-grained residual soil with alluvial soils near river.	Fine-grained residual soils developed from bedrock and alluvial soils near the streams adjacent to the plant site overlying limestones, shales and sandstones should provide a medium for groundwater flow amenable to analysis, although local anomalies may occur. Precipitation is seasonal and net evaporation occurs during the year, somewhat limiting local infiltration in groundwater recharge.
Thomas Hill		Inadequate data for geotechnical evaluation.	
Acme - Toledo Edison Company/Lucas County, OH, 41°-39'-20" N, 83°-29'-45" W (Pond)	B-	30.5" avg. annual precip. (gross), -5" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 20" avg. Near northern border of region. Undifferentiated Quaternary lake deposits of sands, silts, and clays. Mississippian shales and limestones.	Low annual precipitation, with net evaporation, and moderate cross action should limit local infiltration and local groundwater recharge; a regional flow system may predominate. Undifferentiated lake deposits of sands, silts and clay over shales and limestones may make for a complicated flow system, difficult to analyze and interpret.
Bay Shore - Toledo Edison Company/Lucas County, OH, 41°-41'-06" N, 83°-26'-18" W	B-	30.5" avg. annual precip. (gross), -5" net; avg. annual temp. = 50°F, range -10° to 95°; frost penetration = 20" avg. Quaternary undifferentiated lake deposits overlying Silurian limestones. Near northern border of region.	Net evaporation and low seasonal precipitation should make for only limited recharge to the groundwater flow system at this site. The undifferentiated sands, silts and clays of the substrata, overlying limestones, should create a very complex flow pattern, very difficult if not impossible to monitor and evaluate.
Beckjord - Cincinnati Gas nd Electric/Clermont County, OH, 38°-59'-31" N, 84°-17'-53" W (Pond - 38°-59'-31" N, 84°-17'-53" W; landfill is 1 mile from plant)	B	40" avg. annual precip. (gross), 8"-10" net; avg. annual temp. = 55°F, range -5° to 95°; frost penetration = 15". Ordovician limestones and shales below Ohio River sandy alluvium; residual soils.	Net precipitation and very moderate cross action combined to create conditions for significant infiltration and local groundwater recharge at this site. Some residual soils and sandy alluvium beneath the plant should create a good flow medium. Fine-grained residual soils above limestones and shales beneath the landfill for the plant may make flow analysis beneath the landfill more difficult.
Hutchings		Inadequate data for geotechnical evaluation.	

Table 3.5.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Miami Fort - Cincinnati Gas and Electric/Hamilton County, OH, 39°-06'-43" N, 84°-48'-17" W (490 miles downstream from Pittsburgh, on Ohio River near Miami River)	B-	40" avg. annual precip. (gross), 8"-10" net; avg. annual temp. = 55°F, range -5° to 95°; frost penetration = 15". Water table 10' below pond, on site. Landfill 5 miles from site; water table 50' below fill. Ordovician LS and Sh (and marls), overlain on ridges by fine-grained residual soils and sandy alluvium near river.	Significant net precipitation and only moderate frost penetration create local groundwater recharge, as evidenced by a water table at approximately three meters depth at the site. Alluvial soils beneath the interim pond at the plant site should provide a good medium for flow analysis. However, residual soils over limestone and shale beneath the landfill, eight kilometers from the plant site, may be very difficult to analyze in terms of groundwater flow patterns and possible leachate migration.
Stuart		Inadequate data for geotechnical evaluation.	
Tait		Inadequate data for geotechnical evaluation.	
Cumberland - TVA/Stewart County, TN, 36°-23'-39" N, 87°-39'-37" W (on Lake Barkley)	B	49" avg. annual precip. (gross), 12" net; avg. annual temp. = 58°F, range 0° to 100°; frost penetration = 10" per winter season. Mississippian limestones and shales of St. Genevieve, St. Louis, and Salem-Warsaw formations. Clayey residual soils and Cumberland River mixed texture alluvium. Depth to water table varies with level of Lake Barkley. Pond depth is 36'. Severely faulted bedrock area.	Net precipitation and abundant seasonable precipitation, with only shallow frost penetration, make for significant local groundwater recharge at this site. Clayey residual soils mixed with alluvium near the lake at the site make for erratic flow media. The water table at the site varies with the level of Lake Barkley, and this condition may make interpretation of flow data very difficult. Cross flow between broken bedrock zones and the alluvial materials beneath the plant site also could occur to further complicate the flow pattern.
Gallatin - TVA/Sumner County, TN, 36°-20'-03" N, 86°-25'-00" W (on Old Hickory Lake; near	B-	51" avg. annual precip. (gross), 14" net; avg. annual temp. = 58°F, range 0° to 100°; frost penetration = 20" per winter season. Pond depth is 12'; water table varies with level of Old Hickory Lake. Ordovician shaley limestones. Fine-grained residual soils.	Fine-grained residual soils over shaley limestones constitute a flow medium of doubtful utility for the purposes of this study. The water levels in the plant area vary with the level of Old Hickory Lake, and this condition further complicates analysis of flow patterns. The possibility exists for significant flow through the underlying limestone bedrock in a very erratic manner.

Table 3.5.5

OTHER SITE SELECTION RATINGS FOR DISPOSAL OPERATIONS IN THE INTERIOR LOWLANDS REGION (REGION D)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. >7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Colbert, TVA	FA/BA Pond 3+	0	+	0	0	0	0	+	+	0	0	0	+	0	-
Baldwin, Il. Power	FA/BA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	0
Coffeen, Cen. Il. Pub. Ser.	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Crawford, Com. Edison	NA 3+	+	0	0	0	+	0	NA	NA	NA	NA	NA	+	NA	NA
Duck Creek, Cen. Il. Light	FA/FGD Pond 2+	+	0	0	0	0	0	NA	NA	0	0	NA	NA	+	NA
	BA Pond 1+	+	0	0	0	0	0	NA	NA	0	0	NA	NA	NA	NA
Edwards, Cen. Il. Light	FA/BA Pond 1+	+	0	0	0	0	0	NA	NA	0	0	0	+	NA	-
Fisk, Com. Edison	NA 2+	+	0	0	0	+	0	NA	NA	NA	NA	NA	NA	NA	NA
Hennepin, Il. Power	FA/BA Pond 1+	+	0	0	0	0	0	NA	NA	0	0	0	+	NA	-
Hutsonville, Cen. Il. Pub. Ser.	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Joliet, Com. Edison	FA/BA Pond 3+	+	0	0	0	+	0	+	NA	0	0	0	+	NA	-
Kincaid, Com. Edison	FA Fill 1+	0	0	0	0	0	0	NA	NA	+	0	0	NA	NA	NA
	BA Pond 2+	0	0	0	0	0	0	NA	NA	0	0	0	+	+	NA

Table 3.5.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. ≥7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or -)
Brown, South. In. Gas & Elec.	FA/FCD Fill 2+	0	0	0	0	0	0	NA	NA	+	NA	NA	NA	+	NA
Cayuga, Pub. Ser. Co. of Indiana	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Cliffty Cr., In. - Ky. Electric	FA Pond 3+	0	0	0	0	0	0	+	NA	0	NA	0	+	+	NA
	BA Ponds 2+, 1+	0	0	0	0	0	0	NA	NA	0	NA	0	+	+, NA	NA, -
Culley, South. In. Gas & Elec.	BA/FA Pond 2+	0	0	0	0	0	0	NA	NA	0	0	0	+	+	0
Gallagher, Pub. Ser. Co. of Indiana	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Gibson Station Pub. Ser. Co. of Indiana	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Hoosier, Hoos. Eng. Div./In. Rec.	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Michigan City, North. In. Pub. Ser.	Offsite Fill *	0	0	0	0	0	NA	NA	NA	+	NA	NA	NA	NA	-
	BA/FA Pond 1+	0	0	0	0	0	NA	+	NA	0	0	0	0	+	-
Mitchell, North. In. Pub. Ser.	NA 1+	+	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Petersburg, In. P&L	FA/FCD Fill 2+	0	0	0	0	0	0	–	NA	+	0	+	NA	+	NA

Table 3.5.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. ≥7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Marion, Southern Il. Power Coop.	FA/BA/FGD Landfill 2+	0	0	0	0	0	0	NA	NA	+	NA	0	NA	+	NA
Meredosia, Cen. Il. Pub. Ser.	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Newton, Cen. Il. Pub. Ser.	FA/FGD Landfill 3+	0	0	0	0	0	0	NA	NA	+	0	+	NA	+	NA
Powerton, Com. Edison	Ash Fill 6+	+	0	0	0	0	0	+	NA	+	+	0	++	0	NA
Wallace, Cen. Il. Light	BA/FA Pond *	0	0	0	0	0	0	NA	NA	0	0	0	+	0	-
Waukegan, Com. Edison	NA 2+	0	0	0	0	+	0	NA	NA	NA	NA	NA	+	NA	NA
Will County, Com. Edison	FA/FGD Landfill 3+	+	0	0	0	+	0	NA	NA	+	0	0	NA	+	-
	Int. Pond 2+	+	0	0	0	+	0	NA	NA	0	NA	0	NA	NA	NA
Wood River, Il. Power	FA/BA Pond 1-	0	0	0	0	0	0	NA	NA	0	0	0	0	0	-
Bailly, North. In. Pub. Ser.	FA Fill 4+	+	0	0	0	0	NA	NA	NA	+	0	0	+	+	NA
	BA Pond 3+	+	0	0	0	0	NA	+	NA	0	0	0	NA	+	NA
Breed, In. & Mi. Electric	FA Fill 2+	0	0	0	0	0	0	-	NA	+	0	0	+	+	NA
	BA Pond 1+	0	0	0	0	0	0	+	NA	0	0	0	+	0	-

Table 3.5,5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. ≥7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Pritchard, In. P&L	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Schafer, North. In. Pub. Ser.	NA 1+	+	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
State Line, Com. Ed. In.	NA 1+	+	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Stout, In. P&L	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Tanners Cr., In. & Mi. Electric	FA Pond 3+	0	0	0	0	0	0	-	NA	0	+	0	++	+	NA
	BA Pond 1-	0	0	0	0	0	0	NA	NA	0	0	0	NA	NA	-
Wabash River, Pub. Ser. Co. of Indiana	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Des Moines, Iowa P&L	NA 2+	+	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
George Neal, Iowa Pub. Service	BA/FA Pond 3+	+	0	+	0	0	0	+	NA	0	0	0	NA	NA	NA
Kapp, Interstate Power	FA/BA Int. Pond 2+	+	0	0	0	0	0	+	NA	0	0	0	NA	NA	NA
Lansing, Interstate Power	FA/BA Pond 4+	+	0	+	0	0	0	+	NA	0	0	0	+	NA	NA
Brown, Ky. Utilities	FA/BA Pond *	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	-

Table 3.5.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. ≥7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Paradise, TVA	FA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	NA
	BA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	NA
	BA Fill 1+	0	0	0	0	0	0	NA	NA	+	NA	NA	NA	+	-
Reid, Big Rvs. Rur. Elec. Coop.	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Smith, Owensboro Municipal Utilities	FA Fill 1+	0	0	0	0	0	0	NA	NA	+	NA	NA	NA	+	-
	FA/BA Pond 1+	0	0	0	0	0	0	+	NA	0	0	0	+	NA	-
	FA Pond 1+	0	0	0	0	0	0	NA	NA	0	NA	NA	+	NA	NA
Spurlock, E. Ky. Rur. Elec. Coop.	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Labadie, Union Elec.	FA/BA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	NA
Sibley, Mo. Pub. Ser.	NA 2+	0	0	0	0	0	+	NA	NA	NA	NA	NA	+	NA	NA
Sioux Union Elec.	FA/BA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	NA
Thomas Hill, Ass. Elec. Coop.	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Acme, Toledo Edison	BA Fill 1+	0	0	0	0	0	0	NA	NA	+	NA	0	NA	NA	NA
	FA Pond 2+	0	0	0	0	0	0	NA	NA	0	0	0	+	+	NA

Table 3.5.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. >7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Cane Run Louisville Gas & Elec.	FGD/FA/BA Pond 2+	0	0	0	0	0	0	+	NA	0	NA	0	+	+	-
	FGD/FA/BA Fill *	0	0	0	0	0	0	-	NA	+	+	0	NA	+	=
Coleman, Big Rivers Rural Elec. Coop.	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Cooper, East Ky. Rur. Elec. Coop.	NA 1+	0	+	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Ghent, Kentucky Utilities	FA/BA Pond *	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	-
Green River, Kentucky Utilities	FGD Pond 2+	0	0	0	0	0	0	NA	NA	0	0	0	+	+	NA
	FA/BA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	NA
Mill Creek, Louisville Gas & Elec.	FGD/BA/FA Pond 2+	0	0	0	0	0	0	+	NA	0	NA	0	+	+	-
	FGD/BA/FA Fill 2+	0	0	0	0	0	0	-	NA	+	+	0	NA	+	NA
Paddy's Run, Louisville Gas & Elec.	FA/FGD Fill 4+	0	0	0	0	0	0	NA	NA	+	NA	+	+	++	-
	FA/BA Pond 1+	0	0	0	0	0	0	+	NA	0	NA	0	+	NA	-

Table 3.5.5 (Continued)

Plant & Utility	Total Rating (+ and -)	REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate			Contaminant Migration Factor (Climate and Soils) (+)	Water Use		Setting		Mitigative Controls			Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
		Temp. ≥7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤150 Frost-Free Days (+)		G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)			
Bay Shore, Toledo Edison	FA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	0
Beckjord, Cincinnati Gas & Elec.	FA Fill 1+	0	0	0	0	0	0	NA	NA	+	0	0	+	NA	-
	FA/BA Pond 3+	0	0	0	0	0	0	+	NA	0	0	0	++	NA	NA
Hutchings, Dayton P&L	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Miami Fort, Cincinnati Gas & Elec.	FA Fill 1+	0	0	0	0	0	0	NA	NA	+	0	0	+	NA	-
	FA/BA Pond 3+	0	0	0	0	0	0	+	NA	0	0	0	++	NA	NA
Stuart, Dayton P&L	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Tait, Dayton P&L	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Cumberland, TVA	BA/FA Pond 2+	0	+	0	0	0	0	NA	NA	0	0	0	+	NA	NA
Gallatin, TVA	BA/FA Pond 2+	0	+	0	0	0	0	NA	NA	0	0	0	+	NA	NA

Key:
NA = Information not available
0 = Not applicable
* = Sum of + and - is zero
ppt. = Precipitation
G.W. = Groundwater
S.W. = Surface water

Note: Rating methodology is described in Sec. 2.8; information on plants is summarized in Exhibit D.

Given the number of facilities and diversity of disposal practices found in Region D. attempts were made to focus on the most suitable candidate and back-up sites which allowed coverage of the range of options less available in other regions. Consequently, the effort did not focus exclusively on the predominant mode of waste disposal, combined fly and bottom ash ponding. In addition, the future growth of FGD systems in this region was expected to be considerable (see Table 2.4.7), so emphasis was placed on selecting at least one of the 10 plants with operating FGD systems for studying the disposal of FGD waste.

The recommended candidate and back-up sites are shown below:

Waste Type/Disposal Mode	Candidate Sites	Back-Up Sites
Coal Ash		
Fly Ash/Landfill (AL) (off-site) Bottom Ash/Landfill (AL) (off-site)	Powerton	---
Fly Ash/Pond (CS) Bottom Ash/Pond (CS)	Clifty Creek	---
Combined Fly & Bottom Ash/Pond (UL)	---	George Neal
Coal Ash and FGD Wastes		
Fly Ash/FGD/Pond (UL) Bottom Ash/Pond (UL)	---	Duck Creek

Table 3.5.6 provides an overview on the sites' characteristics. A brief description of these sites follows.

Powerton, Commonwealth Edison

Powerton of Commonwealth Edison was designated as a candidate site. This 450-Mw plant disposed of its fly ash in an off-site landfill and bottom ash to an off-site landfill. The landfill received 75% fly ash and 25% bottom ash. The landfill was 121,000 square meters (30 acres) by 9 meters (30 feet) deep and lined with Poz-o-pac. There were about five wells surrounding the landfill which was approximately six years old.

The landfill is located 1.5 kilometers (one mile) from the plant. The utility had indicated that it may be willing to cooperate. Selection was suggested since it represents an important disposal method.

Table 3.5.6

RECOMMENDED CANDIDATE AND BACK-UP SITES - APPALACHIAN REGION - REGION D

	Candidate	Description	Assessment of Disposal Operations	Geotechnical/Hydrogeologic Considerations	Other Factors
1	Powerton Commonwealth Edison Tazewell County, Illinois	1785-Mw plant started up in 1972. Fly ash and bottom ash disposal in an artificially lined off-site landfill.	Off-site landfill. Important disposal method and mitigative practice employed.	Climate limits groundwater recharge. Liner limits migration of leachate. Soil conditions acceptable.	Fly ash disposal impact is important. Baseline study available, extreme temperatures, mitigative liner.
			2 1/2+	B-	6+
2	Clifty Creek Indiana Kentucky Electric Jefferson County, Indiana	1303-Mw plant started in 1955. Fly ash and bottom ash to separate clay substrate lined ponds.	Separate ponds with mitigative practices employed.	Low net precipitation limits groundwater recharge. Clay impedes leachate and groundwater flow.	Placed liner may reduce impacts, separate ponds available.
			2+	B-	3+ (Fly ash pond) 2+ 1+ (Bottom ash ponds)
	Back-up				
3	George Neal Iowa Public Service Woodbury County, Iowa	961-Mw plant started up in 1964. Combined fly and bottom ash disposal in an unlined pond.	Typical disposal method for region.	Climate limits groundwater recharge; alluvial soils, position of water table and monitoring wells promote understanding.	Region of extreme temperatures, favorable combination of age and substrate.
			2 1/2+	B	3+
4	Duck Creek Central Illinois Light Fulton County, Illinois	441-Mw plant started up in 1976, FGD in 9/76. Fly ash /FGD waste disposal in an unlined pond; bottom ash in an unlined pond.	Important co-disposal method and mitigative practice employed.	Silty soil with sand and gravel lenses create complex flow. Moderate frost penetration does not constrain frost penetration.	FGD waste impact important in area. Acceptable setting.
			3+	B-	2+ (Fly ash/FGD) 1+ (Bottom ash)

Clifty Creek, Indiana Kentucky Electric

Clifty Creek of Indiana Kentucky Electric was designated as a candidate site. It is a large plant which disposed of fly ash and bottom in separate lined ponds. The plant apparently had a cyclone-fired boiler resulting in a greater percentage of bottom ash than usual in large boilers. The ponds were reportedly underlain by 5 meters (15 feet) of clay which would serve to limit leachate flow. This plant represented an important disposal mode for this environmental setting.

George Neal, Iowa Public Service

George Neal of Iowa Public Service was designated as a back-up site. This 961-Mw plant disposed of its combined fly and bottom ash in an unlined pond. This is a typical disposal practice for this region. Hydrogeologic conditions appeared favorable. George Neal was a potential back-up to Allen and Widows Creek with regard to the ponding of combined fly and bottom ash in unlined ponds.

Duck Creek, Central Illinois Light

Duck Creek of Central Illinois Light was designated as a back-up site. This 441-Mw plant practiced co-disposal of FGD wastes and fly ash in unlined ponds. Bottom ash was disposed of in an unlined pond. Soil conditions appeared to create somewhat of a complex flow. Duck Creek was suggested as a back-up site to both Sherburne County and Colstrip since co-disposal impacts could be studied there. In addition, Duck Creek was a potential back-up to such plants as Sherburne County and Columbia with respect to the separate ponding of bottom ash.

Some other sites considered interesting in this region (not in any special order) were:

- Baldwin, Illinois Power
- Edwards, Illinois Power/Central Illinois Light
- Bailly, Northern Indiana Public Service
- Paddys Run, Louisville Gas & Electric
- Smith, Owensboro Municipal Utilities
- Labadie, Union Electric
- Sioux, Union Electric
- Miami Fort, Cincinnati Gas & Electric

3.6 REGION E: OZARK REGION

3.6.1 Background

The Ozark Region includes most of southern and central Missouri, northwestern Arkansas, and portions of eastern Oklahoma.

As of 1977, this region had four coal-fired (greater than 80% of power generated from coal) power plants with a total capacity of 2417 Mw. Three of these had individual capacities of greater than 190 Mw and are considered further in this section. Table 3.6.1 summarizes the baseline data for these plants. Meramec Station, with a capacity of 923 Mw, started-up* in 1953. Rush Island Station, capacity 1241 Mw, started-up in 1976. Both are located on the Mississippi River south of St. Louis. Southwest with a capacity of 194 Mw, started up in 1976. Located near Springfield, Missouri, its FGD system (the only one in the region) began operation in 1977. This plant was included as a potential candidate site even through it was <200 Mw because it employed an FGD system.

This physiographic region and the prevailing climatic conditions are described in detail in Exhibit C. Average annual gross precipitation ranges anywhere from 102 to 114 cm (40 to 45 in.) roughly from west to east. Characteristic moderate ambient temperatures for this region range from 24 to 35°C (75 to 95°F), while the average annual temperature is 13 to 18°C (55 to 65°F). The region is characterized by rolling plateau land, mostly more than 300 meters (1000 feet) above sea level. Surface soils are mostly residual deposits formed by weathering of underlying sedimentary bedrock (this bedrock being of both marine and continental origin). Frost penetration varies from approximately 25 cm (10 in.) in central Arkansas to approximately 38 cm (15 in.) in central Missouri.

3.6.2 Assessment of Disposal Operations

3.6.2.1 Categorization of Disposal Operations

Table 3.6.2 presents a summary of waste disposal methods in Region E. The utility operations of the Ozark Region employed one of two disposal practices for their wastes:

- combined fly ash and bottom ash ponding was practiced at Meramec and Rush Island, and
- Southwest practiced landfilling of fly ash and FGC waste and interim ponding/landfilling of bottom ash.

3.6.2.2 Assessment of Disposal Operation

Table 3.6.3 presents the results of the disposal operation assessment rating for Region E. The methodology employed in making this assessment is described in Section 2.6. One plant warrented further evaluation based on this rating alone. It was the Southwest plant.

---

*Date on which coal became the primary source of fuel.

Table 3.6.1

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN OZARK REGION (E) OF THE U.S.

Plant Name	Utility Name	Capacity (Mw)[b,e]		State	County	Start-up Date		Waste Type[f]	Disposal Method[e,f]
		Nameplate Generating	FGD Scrubbed			Plant[c,d]	FGD[e]		
Meramec[*]	Union Electric	923	--	MO	St. Louis	-/53	--	Comb. Fly & Bottom	Pond(UL)
Rush Island[*]	Union Electric	1,241	--	MO	Jefferson	-/76	--	Comb. Fly & Bottom	Pond(UL)/sold
Southwest[*i]	Springfield City Utilities	194	194	MO	Greene	6/76	4/77	Fly Ash/FGD(non-prop.) Bottom Ash	Landfill(AL) Interim Pond(AL); Landfill(AL)

Notes follow Table 3.1.1

Table 3.6.2

MATRIX OF FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS ≥ 200 Mw IN THE OZARK REGION (E) OF THE UNITED STATES IN 1979[a]

Type of Waste	Number of Plants		
	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	-	-	-
Bottom ash only	-	-	1
Combined fly and bottom ash	2	-	-
FGD waste only	-	-	-
Mixed fly ash and FGD waste	-	-	-
Mixed bottom ash and FGD waste	-	-	-
Mixed fly ash and FGD waste (stabilized)	-	1	-
Mixed fly ash, bottom ash, and FGD waste	-	-	-

---

[a] Coal-fired plants (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal.

Source: Compiled by Arthur D. Little, Inc. based on Utility Plant Data Survey Sheets used in developing reference (1).

Table 3.6.3

ASSESSMENT OF DISPOSAL OPERATIONS IN OZARK REGION (E) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Meramec		1 1/2+	0	0	1 1/2+	Extraneous pond influents include coal pile run-off and boiler blowdown. Ash pond to reach its design life in 1981.
Rush Island		1 1/2+	0	0	1 1/2+	Extraneous pond influents include coal pile run-off and boiler blowdown.
Southwest		1 1/2+	1+	1+	3 1/2+	Bottom ash pond and landfill are 2 years old. Bottom ash pond is lined with asphalt and landfill is lined with Poz-O-Pac.

---

[a] Assessment rating system explained in Section 2.6.

3.6.3 Geotechnical and Hydrogeologic Considerations

Table 3.6.4 presents an evaluation of the geotechnical and hydrogeologic considerations and subsequent ratings for the sites in Region E. The methodology employed in making this assessment is presented in Section 2.7.

3.6.4 Other Site Selection Considerationss

Table 3.6.5 presents the ratings for other site selection considerations for the disposal operations in Region E. Discussion of the rating methodology is presented in Section 2.8, and the individual plants are discussed in Exhibit D.

3.6.5 Candidate and Back-Up Sites

While one candidate site was targeted for this region, the combined ratings for the plants were not particularly attractive. The only potential exception was Southwest of Springfield City Utilities which practiced co-disposal of FGD waste and fly ash in a landfill. In addition, the bottom ash pond was reportedly lined with asphalt and the landfill with Pox-o-pac. Southwest, being a small plant (194 Mw), could have provided baseline data on disposal costs for even smaller plants employing this type of disposal method. A preliminary hydrogeologic evaluation indicated that monitoring efforts may be hampered due to the fact that the plant is situated in a broad region of limestone residual soil. Detailed information on the site was unavailable. Southwest Station was tentatively recommended as a candidate site, pending a further evaluation of site conditions.

Waste Type/Disposal Method	Candidate Sites	Back-Up Sites
Bottom Ash/Interim Pond (AL); Landfill (AL)	Southwest	---
Fly Ash/FGD Wastes/Landfill (AL)		

Table 3.6.4

GEOTECHNICAL/HYDROGEOLOGIC RATING OF SITES - REGION E

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Meramec - Union Electric/ St. Louis, MO, at confluence of Meramec and Mississippi Rivers (In Region E, but only 25 miles south of Missouri River, which is the border between Regions D and E)	B	36" avg. annual precip. (gross), -5±"net; avg. annual temp. = 55°F, range -5° to 100°; frost penetration = 20" avg. Mississippian cherty and oolitic limestones. Limestone fine-grained residual soil, with sandy, silty alluvium near river; some thin loess cover.	Net evaporation and only slight seasonal precipitation make for limited infiltration and local recharge of groundwater flow at this site. Groundwater flow in the alluvium near the site will be governed by a flow pattern in the Mississippi River. Fine grained residual soils developed over limestone predominate in areas away from the river and may complicate flow patterns. Some cross flow may occur between subsoils and the limestone bedrock.
Rush Island - Union Electric/ Jefferson County, MO		36" avg. annual precip. (gross), about -5" net; avg. annual temp. = 55°F, range = -5° to 100°. Frost penetration = 20" avg. per winter season.	Inadequate data for geotechnical evaluation.
Southwest Station - Springfield City Utilities/Springfield, MO, 37°09'oo" N, 90°23'07" W	C (tentative)		Inadequate data for complete geotechnical evaluation. Plant's location in broad region of limestone residual soil could potentially hamper monitoring efforts.

Table 3.6.5

OTHER SITE SELECTION RATINGS FOR DISPOSAL OPERATIONS IN THE OZARK REGION (REGION E)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. >7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Meramec, Union Elec.	FA/BA Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	NA
Rush Island, Union Elec.	FA/BA Pond *	0	0	0	0	0	0	NA	NA	0	0	0	NA	NA	NA
Southwest, Springfield City Util.	Combined FA/FGD Fill 2+	0	0	0	0	0	0	-	NA	+	+	0	+	+	-
	BA Int. Pond *	0	0	0	0	0	0	-	NA	0	0	0	+	NA	NA

Key:
NA = Information not available
0 = Not applicable
* = Sum of + and - is zero
ppt. = Precipitation
G.W. = Groundwater
S.W. = Surface water

Note: Rating methodology is described in Sec. 2.8; information on plants is summarized in Exhibit D.

Table 3.6.6

RECOMMENDED CANDIDATE SITE - REGION E - OZARKS

Candidate	Description	Assessment of Disposal	Geotechnical/ Hydrogeologic Considerations	Other Factors
Southwest Station Springfield City Utilities Greene County, MO	194-Mw plant started up in 1976. Fly ash/FGD waste landfilled. Bottom ash disposal to an interim pond then to a landfill.	Important small size plant practicing fly ash/FGD waste co-disposal. Landfill lined with Poz-o-Pac. Plant had some operational problems to overcome.	Plant's location on limestone residual soil could potentially cause very erratic infiltration, leaching, and groundwater flow which could hamper monitoring efforts.	Surface water use important in area, mitigative practice employed, age and substrate appears unfavorable.
		3 1/2+	C (tentative)	2+ (Fly ash/FGD fill) * (Bottom ash interim pond)

No Back-up Site in Region.

Plant generating capacities ranged from a low of 200 Mw to a high of 3279 Mw. Nineteen of the plants fell in the 200 to 950 Mw range, while the other three exceeded 1600 Mw. The oldest plant began service (as of 1979) 56 years prior, with the range of year** of first service being from 1924 through 1975. Only five plants had started operation in the prior 20 years. There were no operational FGD systems in the region as of mid-1979.

3.7 REGION F: GREAT LAKES REGION

3.7.1 Background

The Great Lakes Region includes all of Michigan, Wisconsin, the northeastern corner of Minnesota, and the areas of New York along the Great Lakes.

As of 1977, this region had 43 coal-fired (greater than 80% of power generated from coal) power plants iwth a total capacity of 17, 680 Mw.* Twenty-two of these plants, with a capacity of 15,848 Mw, had individual capacities greater than 200 Mw and are considered further in this section. Table 3.7.1 summarizes baseline data for these plants. They are generally located (a) along the Great Lakes, and (b) along the Mississippi River.

Plant Generating capacities ranged from a low of 200 Mw to a high of 3279 Mw. Nineteen of the plants fell in the 200 to 950 Mw range, while the other three exceeded 1600 Mw. The oldest plant began service (as of 1979) 56 years prior, with the range of a year** of first service being from 1924 through 1975. Only five plants had started operation in the prior 20 years. There were no operational FGD systems in the region as of mid-1979.

This physiographic region and the prevailing climatic conditions are described in detail in Exhibit C. Average annual gross precipitation ranges from 89 cm (35 in.) in southeastern Michigan to 64 cm (25 in.) in eastern Minnesota. Temperatures for this region range from about -40°C (-40°F) to 35°C (95°F), while the average annual temperature ranges from 7°C (45°F) in southern Wisconsin to 3°C (37°F) in eastern Minnesota. Except for eastern Minnesota (containing no power plants under consideration), the land is relatively flat, dominated by numerous features of glacial origin. Surface soils vary from sandy outwash deposits to extremely fine grained lacustrine deposits. Frost penetration is a major factor, increasing from 76 cm (30 in.) in southern Michigan to 127 cm (50 in.) in eastern Minnesota.

---

*One plant was included even though it was <80% coal-fired in 1977 because it shared a land disposal site with the St. Clair and Trenton Channel plants.

**Date on which coal became the primary source of fuel.

Table 3.7.1

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN GREAT LAKES REGION (F) OF THE U.S.

Plant Name	Utility Name	Capacity (Mw)[b,e] Nameplate Generating	Capacity (Mw)[b,e] FGD Scrubbed	State	County	Start-up Date Plant[c,d]	Start-up Date FGD[e]	Waste Type[f]	Disposal Method[e,f]
Campbell*	Consumers Power	650	--	MI	Ottawa	-/62	--	Fly Ash Bottom Ash	Pond(UL) Interim Pond(UL);sold
Cobb*	Consumers Power	510	--	MI	Muskegon	-/48	--	Fly Ash Comb. Fly & Bottom	Landfill(UL) Interim Pond(UL); Landfill(?)
Conners Creek*	Detroit Edison	540	--	MI	Wayne	3/51	--	Fly Ash Comb. Fly & Bottom	Landfill(UL)/sold Interim Pond(AL); Landfill(UL)/sold
Eckert*	Lansing Board of Water & Light	386	--	MI	Ingham	-/54	--	Fly Ash Bottom Ash	Landfill (off-site) Hydrobin; Landfill (off-site)
Marysville*	Detroit Edison	200	--	MI	St. Clair	10/30	--	Fly Ash Bottom Ash	Landfill(UL)(off-site) Interim Pond(UL); Landfill(UL)(off-site)
Monroe*	Detroit Edison	3,279	--	MI	Monroe	5/71	--	Fly Ash Bottom Ash	Pond(UL) Pond(UL)
Presque Isle*	Upper Peninsula Generating	301	--	MI	Marquette	9/55	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL)
River Rouge*[g]	Detroit Edison	933	--	MI	Wayne	11/57	--	Fly Ash Comb. Fly & Bottom	Landfill(UL) Interim Pond(UL); Landfill(UL)
St. Clair*	Detroit Edison	1,905	--	MI	St. Clair	11/53	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL)
Trenton Channel*	Detroit Edison	775	--	MI	Wayne	-/24	--	Fly Ash Comb. Fly & Bottom	Landfill(UL)/sold Interim Pond(UL); Landfill(UL)
Whiting	Consumer Power	325	--	MI	Monroe	-/52	--	NA	NA
Dunkirk*	Niagara Mohawk Power	628	--	NY	Chautauqua	-/50	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(UL); Landfill(UL)
Huntley*	Niagara Mohawk Power	828	--	NY	Erie	-/42	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(CS,AL,UL); Landfill(UL)
Rochester #7*	Rochester Gas & Electric	252	--	NY	Monroe	-/49	--	Fly Ash Bottom Ash	Landfill(?) Hydrobin;Landfill(?)
Columbia I*	Wisconsin Power & Light	556	--	WI	Portage	5/75	--	Fly Ash Bottom Ash	Pond(UL) Pond(UL)
Edgewater*	Wisconsin Power & Light	477	--	WI	Sheboygan	-/31	--	Bottom Ash Comb. Fly & Bottom	Sold Pond(UL)
Genoa #3*	Dairyland Power Coop.	345	--	WI	Vernon	7/69	--	Comb. Fly & Bottom	Pond(UL)

Table 3.7.1 (continued)

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN GREAT LAKES REGION (F) OF THE U.S.

		Capacity (Mw)[b,e]				Start-up Date			
Plant Name	Utility Name	Nameplate Generating	FGD Scrubbed	State	County	Plant[c,d]	FGD[e]	Waste Type[f]	Disposal Method[e,f]
Nelson Dewey*	Wisconsin Power & Light	227	--	WI	Grant	-/59	--	Comb. Fly & Bottom	Pond(UL)/sold
Oak Creek	Wisconsin Electric Power	1,670	--	WI	Milwaukee	-/53	--	NA	NA
Port Washington	Wisconsin Electric Power	400	--	WI	Ozaukee	-/35	--	NA	NA
Pulliam	Wisconsin Public Ser.	.392	--	WI	Brown	1/43	--	NA	NA
Valley	Wisconsin Electric Power	269	--	WI	Milwaukee	-/68	--	NA	NA

Footnotes follow Table 3.1.1

3.7.2. Assessment of Disposal Operations

3.7.2.1 Categorization of Disposal Operations

Table 3.7.2 presents summary data on the disposal methods practiced in Region F. The utility operations of the Great Lakes Region typically employed one or more of two basic disposal practices for fly ash and bottom ash:

- single-step landfill disposal for fly ash, and
- interim ponding followed by final landfill disposal for bottom ash separately and for combined fly and bottom ash.

Fly ash disposal in landfills was practiced at 11 out of the 17 plants in this region on which information was available. Two of the plants in this region practiced landfill disposal for bottom ash.

A general overview of the major types of disposal practiced in this region is briefly presented below.

Disposal of Fly Ash in Landfills

Of the 17 plants in this region on which the investigators had sufficient data (see Table 3.7.1), 11 were known to rely on single-step landfill disposal. These were Cobb, Conners Creek, Eckert, Marysville, Presque Isle, River Rouge, St. Clair, Trenton Channel, Dunkirk, Huntley, and Rochester #7. In addition, nine of these plants also practiced interim ponding followed by landfill disposal of either bottom ash or combined fly and bottom ash.

Disposal of Bottom Ash in an Interim Pond Followed by a Landfill

Of the 17 plants listed in Table 3.7.1 on which the investigators had sufficient data, there were five which interim ponded then landfilled their bottom ash. Four plants interim ponded then landfilled combined fly and bottom ash. These were all a subset of the aforementioned plants practicing the landfilling of fly ash, and included Marysville, Cobb, Conners Creek, Presque Isle, River Rouge, St. Clair, Trenton Channel, Dunkirk, and Huntley.

Table 3.7.2

MATRIX OF FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS

> 200 Mw IN THE GREAT LAKES REGION (F) OF THE UNITED STATES IN 1979[a]

	Number of Plants		
Type of Waste	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	3	11	-
Bottom ash only	3	2	5
Combined fly and bottom ash	3	-	4
FGD waste only	-	-	-
Mixed fly ash and FGD waste	-	-	-
Mixed bottom ash and FGD waste	-	-	-
Mixed fly ash and FGD waste (stabilized)	-	-	-
Mixed fly ash, bottom ash, and FGD waste	-	-	-

---

[a] Coal-fired plants (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal.

Source: Compiled by Arthur D. Little, Inc. based on Utility Plant Data Survey Sheets used in developing Reference (1).

3.7.2.2 Assessment of Disposal Operations

Table 3.7.3 presents the results of the disposal operation assessment rating for Region F. The methodology employed in making this assessment is discussed in Section 2.6. It appeared that only six plants warranted further evaluation. These included Cobb, Eckert, Presque Isle, Dunkirk, Huntley, and Columbia I. Even though the Conners Creek plant has a 3+ rating, it was eliminated from further evaluation due to the complexities involved in its sharing its landfill with two other plants (River Rouge and Trenton Channel). The same was true for the Marysville and St. Clair plants which also shared a landfill at the St. Clair plant. In addition, three other plants (Rochester #7, Edgewater, and Nelson Dewey) were eliminated from consideration due to the disposal site being less than two years old or the fact that the majority of the plant's ash had been sold in recent years. This group of plants was later narrowed down when hydrogeologic and other considerations were taken into account.

3.7.2.3 Comments on Handling and Transportation of Coal Ash

The most prevalent types of ash handling and transportation methods practiced by the plants in this region include the dry handling of fly ash to a landfill (see Table 2.4.4), and wet sluicing of bottom ash to an interim pond or hydrobin where dewatering takes place, prior to a final disposal in a landfill.

3.7.3 Geotechnical and Hydrogeologic Considerations

Table 3.7.4 presents an evaluation of geotechnical and hydrogeologic considerations and subsequent ratings for the sites in Region F. The methodology employed in making this assessment was presented earlier, in Section 2.7.

3.7.4 Other Site Selection Considerations

3.7.4.1 Discussion

Portions of Region F experience significant extremes of temperature, often including fewer than 150 frost-free days per year. Of the 22 plants with disposal operations considered in this region, more than half (14) met one or the other of the temperature-related criteria (or both). One portion of the region, eastern Wisconsin, was reported to be an area experiencing groundwater overdraft and surface water supply depletion in the Second National Water Assessment (21). Five of the plants considered were located in this part of Region F. Discussion of individual plants appears in Exhibit D.

Table 3.7.3

ASSESSMENT OF DISPOSAL OPERATIONS IN GREAT LAKES REGION (F) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Campbell		1 1/2+	0	0	1 1/2+	
Cobb		1 1/2+	1+	1/2+	3+	Fly ash pond will reach its design life in 1980.
Conners Creek		1 1/2+	1+	1/2+	3+	Landfill is shared by River Rouge and Trenton Channel plants.
Eckert		1 1/2+	1+	1/2+	3+	
Marysville		1+	1+	1+	3+	Bottom ash pond < 2 years old. Plant disposes of its coal ash in St. Clair's landfill.
Monroe		1 1/2+	0	0	1 1/2+	Extraneous pond influent is primarily coal pile run-off.
Presque Isle		1 1/2+	1+	1/2+	3+	Closed cycle wet handling system will be employed for bottom ash.
River Rouge		1 1/2+	1+	1/2+	3+	Plant disposes of its coal ash in Conners Creek's landfill.
St. Clair		1 1/2+	1+	1/2+	3+	Extraneous pond influent is water treatment waste. Landfill is shared with Marysville plant. Plant employs a wet particulate scrubber.
Trenton Channel		1 1/2+	1+	1/2+	3+	Plant disposes of its coal ash at Conners Creek's landfill.
Whiting		1/2+	NA	0	NA	
Dunkirk		1 1/2+	1+	1/2+	3+	Extraneous influents to bottom ash pond are classified as miscellaneous material.
Huntley		1 1/2+	1+	1/2+	3+	Two of the four ponds are two years old.
Rochester #7	X	1 1/2+	1+	1/2+	X	Landfill is < 2 years old.
Columbia I		1 1/2+	0	1/2+	2+	Ponds are 4 years old.
Edgewater	X	1 1/2+	0	0	X	Most bottom ash was sold in 1978.
Genoa #3		1 1/2+	0	0	1 1/2+	Pond is 2 years old.
Nelson Dewey	X	1 1/2+	0	0	X	All bottom ash was sold in 1978. Also, a significant quantity of their present coal ash stockpile was sold in 1978.
Oak Creek		1 1/2+	NA	NA	NA	
Port Washington		1/2+	NA	0	NA	
Pulliam		1/2+	NA	0	NA	
Valley		1/2+	NA	1/2+	NA	

---

[a] Assessment rating system explained in Section 2.6.

Table 3.7.4

GEOTECHNICAL/HYDROGEOLOGIC RATING OF SITES - REGION F

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Campbell - Consumers Power/ Ottawa County, MI (FA to pond)		Inadequate data for geotechnical evaluation.	
Cobb - Consumers Power/ Muskegon County, MI, 43°15'17"N, 86°14'31" W	C+	32" avg. annual precip. (gross), -8" net; avg. annual temp. = 45°F; range -15° to 95°; frost penetration = 40" per winter season. Pond is 10' deep; water table at 10'. Quaternary sandy lacustrine deposits. Below pond: 3' rotted wood, over 30' of medium sand. Landfill is 10' thick; 9' to water table. Below landfill: 3' of wood chips over 30' of medium sand.	Net evaporation and low seasonal precipitation, combined with significant thickness of frost penetration during winter months should severely limit local infiltration and local groundwater recharge. Sandy soils beneath the disposal site also contain rotted wood and wood chips which may severely complicate the analysis of water flow and water quality beneath the disposal area.
Conners Creek - Detroit Edison/Wayne County, MI (FA sold or LF. BA → interim pond, then sold or landfilled)	C-	30" avg. annual precip. (gross), -4" net; avg. annual temp. = 48°; range -15° to 95°; frost penetration = 30" avg. per winter season. Pond is about 10' deep, with concrete bottom. Landfill is about 20 miles from plant, in an abandoned section of LS quarry. Residual clay soil around quarry. Part of quarry is active. Devonian limestone. Water quality in dewatering sump: 7000 mg/l TDS and H_2S 70 mg/l.	Net evaporation and low seasonable precipitation combined with very significant frost action during the winter months should severely limit local infiltration and groundwater recharge. The concrete lining beneath the interim pond at the plant site may make the flow pattern around the pond extremely erratic and almost impossible to evaluate. The landfill, 20 miles from the plant in an abandoned section of a limestone quarry, with clay soil around the quarry, may be virtually impossible to monitor. Continued activity in the quarry will also complicate the evaluation of the observed data.
Eckert - Lansing Board of Water, Electric Light Commission/Inghman County, MI (FA handled dry; BA wet-sluiced to pond; BA & FA hauled to commercial landfill for disposal)	C	30.4" avg. annual precip. (gross), -7.6" net; avg. annual temp. = 47°F; range -10° to 95°; frost penetration = 40"; soils consist of Wisconsinan ground till and moraine, bedrock is upper Paleozoic sedimentary rocks, probably predominantly limestone; no data given on interim BA pond.	Net evaporation and low seasonable precipitation combined with very significant frost penetration during the winter months should severely limit local infiltration and groundwater recharge. The surficial soils consisting of glacial deposits of relatively fine grained materials also should drastically retard groundwater flow as well as a leachate movement. Underlying sedimentary rocks containing limestone layers also create the possibility for some cross flow between bedrock and subsoil layers. The existence of a commercial landfill for ultimate disposal of the waste products also would make evaluation very complicated, if not impossible.

Table 3.7.4 (cont.)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Marysville - Detroit Edison/ St. Clair County, MI (FA → LF, BA → pond, then landfilled)	C-	30" avg. annual precip. (gross), -4" net; avg. annual temp. = 48°F, range -20° to 95°; frost penetration = 30" avg. per winter season. BA pond is 8' deep; 100' to water table. 100' of clay under pond. Landfill serves St. Clair Plant also. Devonian LS under Quaternary lake and ground moraine deposits.	Low seasonal precipitation with net annual evaporation and very significant frost penetration work to limit local groundwater recharge. The water table at the plant site is at an extreme depth of over 30 meters and the pond at the site is underlain by more than 30 meters of clay. These conditions would create very slow and very hard to monitor groundwater flow. The depth of over 30 meters to the water table at the landfill site, with clay soil below the landfill, would make monitoring conditions at the landfill extremely difficult.
Monroe - Detroit Edison/ Monroe County, MI (FA to pond #1 , BA etc. to pond # 15)	C	30" avg. annual precip. (gross), -4" net; avg. annual temp. = 48°F, range -10° to 95°; frost penetration = 25" avg. per winter. FA pond is 40' deep; 30' to water table. BA pond is 10' deep; 10' - 20' to water table. 30' clay under FA pond over Silurian LS; 10' - 20' clay under BA pond.	Low seasonal precipitation with net annual evaporation and moderate cross action should limit infiltration and local groundwater recharge. The existence of a water table nine to ten meters below the soil surface and above the bottom of the fly ash pond makes for a complicated analysis of the flow pattern and quality of water samples. Clay soil under the ponds, overlying limestone layers, should make for a very slow flow with the possibility of very slow cross flow into the limestone.
Presque Isle - Upper Peninsula Generating Co./ Marquette County, MI (Pond 46°34'18"N, 87°24'05" W; BA → pond. FA landfilled. Landfill 46°34'15"N, 87°25'07"W, 1.5 miles from plant)	C	31.6" avg. annual precip. (gross), 6" net; avg. annual temp. = 40°F, range -20° to 90°; frost penetration = 50" avg. per winter season. Pond is 5' deep. No data on water table. Landfill is 40' thick; water table at 55'. Lower PreCambrian gabbros and granites. No soil data.	Low net precipitation with low seasonal rainfall and very severe frost penetration should limit infiltration and groundwater recharge, particularly during winter months. Igneous bedrock below the site may limit the flow between bedrock units and subsoils, but subsurface data are inadequate for final evaluation at the present time; more specific site data are required for final rating.
River Rouge - Detroit Edison/ Wayne County, MI (BA → interim pond, then LF. FA landfilled. Landfill is same site as for Conner's Creek Plant)	C-	30" avg. annual precip. (gross), -4" net; avg. annual temp. = 48°F, range -15° to 95°; frost penetration = 30" avg. per winter season. Pond is 12' deep, underlain by 10' of unknown fill over 100' of clay. 100' to potable water. 10 miles to landfill.	Net annual evaporation and low seasonal precipitation combine with moderate frost penetration to limit groundwater recharge. The existence of more than 30 meters of clay below the interim pond at the pond should drastically retard groundwater flow and make analysis very difficult. Three meters of fill of unknown characteristics below the pond may further complicate evaluation and analysis of flow around the pond and analysis of water quality. The landfill in an abandoned section of a limestone quarry would be virtually impossible to monitor and evaluate, for groundwater flow conditions.

Table 3.7.4 (cont.)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
St. Clair - Detroit Edison/ St. Clair County, MI (FA landfilled; BA interim pond, then LF)	C	30" avg. annual precip. (gross), -4" net; avg. annual temp. = 48°F, range -20° to 95°; frost penetration = 30" avg. per winter season. Pond is 10' ± deep; water (potable) at about 100'. 100' of clay below pond, to LS. Devonian LS under Quaternary lake and ground moraine deposits. Landfill 2 miles from plant; landfill 100' thick, and water table at 100'. Clay below LF.	Net annual evaporation and low seasonal precipitation together with more than moderate cross penetration should severely limit local infiltration and local recharge to the groundwater flow system. A very deep regional flow system may predominate. More than 30 meters of clay are found below the interim pond at the plant site, and this clay may make the groundwater and leachate flow extremely slow and difficult to monitor. Similar conditions exist at the landfill site and groundwater monitoring and evaluation at that site also may be extremely difficult.
Trenton Channel - Detroit Edison/Wayne Count, MI (Some 55,000 tons FA sold; most BA, FA sluiced to pond, then landfilled)	C-	30" avg. annual precip. (gross), -4" net; avg. annual temp. = 48°F, range -15° to 95°; frost penetration = 30" avg. per winter season. Pond is about 10' deep; water table at unknown depth. Below pond, 0 - 10' of miscellaneous fill over about 10' of clay over limestone. Middle Devonian LS. Landfill serves several plants. Lake deposits over LS.	The existence of more than three meters of miscellaneous fill below the interim pond at the pond site, with more than three meters of clay soil below the fill and over limestone, should create very slow but possibly very erratic flow conditions and could have an effect on water quality also. Net evaporation and low seasonal precipitation, combined with more than moderate frost action, also should limit local infiltration and recharge to the groundwater flow system.
Whiting		Inadequate Data for geotechnical evaluation.	
Dunkirk - Niagara Mohawk Power/Chautauqua County, NY, 42°18' N, 79°21' W (BA pond → LF, FA → LF. LF 6.5 mi away)	C	40" avg. annual precip. (gross), 2" net; avg. annual temp. = 50°F, range -20° to 95°; frost penetration = 40" per winter season. 8' - 10' clay underlain by shale under 35' - 40' deep landfill; water table at 15'. Pond is 8' deep; (?) to water. Devonian shales. Shore deposits near lake.	Very fine grained clay soils underlain by shale below the disposal area at the landfill should make groundwater monitoring extremely difficult at that site. Similar conditions below the interim pond may also make groundwater evaluation beneath the pond difficult. Low net annual precipitation and rather severe frost action combined to limit local groundwater recharge. These conditions combine to indicate that groundwater monitoring and evaluation could be extremely difficult at this site.
Huntley - Niagara Mohawk Power/Erie County, NY, 42°58' N, 78°55' W (BA pond → LF, FA → LF. LF 1.2 mi away)	C	40" avg. annual precip. (gross), 2" net; avg. annual temp. = 50°F, range -20° to 95°; frost penetration = 40" per winter season. 26' brown silty clay under landfill; LF 25' deep; water table at 26'. Pond is 8' - 12' deep, water table at 4' - 5'. Bedrock is Silurian shale. Fine-grained residual soil. Alluvium along river.	Silty clay soil below the disposal areas at the landfill and at the interim pond at this plant overly shale bedrock. The fine grained nature of the soil and of the bedrock units make for very slow flow, very difficult to monitor and to evaluate. Deep frost penetration and low net annual precipitation limit local groundwater recharge and infiltration, and further complicate analysis.

Table 3.7.4 (cont.)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Rochester # 7 - Rochester Gas & Electric/Monroe County, NY (FA collected in baghouse, then trucked to landfill; BA collected wet and trucked to landfill; landfill 9 mi from plant, contains 20% BA, 80% FA; landfill is contractor operated)		31" avg. annual precip. (gross), 4" net; avg. annual temp. = 45°, range -20° to 90°; frost penetration = 70". One bottom ash pond at plant site (retired), 5' deep, 3 to 5' to water table. Bedrock upper Silurian shales and limestones, no soil data available but most likely glacial outwash deposits and tills.	Inadequate data for geotechnical evaluation.
Columbia I - Wisconsin Power and Light/Columbia County, WI, 43°29'13"N, 89°25'10"W (SW of Portage on Wisconsin River) (BA/FA sluiced to pond. 20/80 BA/FA; 19 monitoring wells; extensive study)	A	32" avg. annual precip. (gross), -6" net; avg. annual temp. = 45°, range -20° to 95°; frost penetration = 45" per winter season. 0' to 10' to water table below pond. Ground moraine, some river alluvium, overlying Cambrian SS and LS.	Low seasonal precipitation and net annual evaporation combine with deep frost penetration to severely limit local recharge to the groundwater table. However, groundwater resources at the site are more than adequate because of the existence of pervious soils beneath the sites and a good hydraulic connection with the Wisconsin River. The soils underlying the site should provide excellent medium for groundwater flow monitoring and evaluation. The existence of a number of monitoring wells already in place at the site, and the relative newness of the disposal operation combine to favor monitoring operations at the site.
Edgewater - Wisconsin Power and Light/Sheboygan County, WI, 43°42'43"N, 87°42'30"W (80/20 BA/FA pond; 83,000 tons FA sold. 7 monitoring wells, 15' - 25' deep)	B-	32" avg. annual precip. (gross), -6" net; avg. annual temp. = 45°, range -20° to 95°; frost penetration = 45" per winter season. Pond is 10' - 20' deep; water table at 0' - 10'. Pond underlain by silty sand. Lake shore deposits.	Although frost penetration is deep during winter months at this site and net evaporation occurs annually at the site, with only low seasonable precipitation, groundwater resources at the site are abundant because of the location near a large source of water and the presence of very pervious soils below the plant site. However, the existence of a very high water table, influenced by an external water body, with a pond bottom well below the water table may create a flow pattern very difficult to evaluate, particularly in view of the age of the plant (39 years).
Genoa # 3 - Dairyland Power Coop./Vernon County, WI, 43°34' N, 91°14' W (20/75 BA/FA pond. 10 wells, 10' - 60' deep. On Mississippi River)	B	30" avg. annual precip. (gross), -2" net; avg. annual temp. = 45°F, range -20° to 95°; frost penetration = 50" per winter season. Pond is 30' deep, 10' to water table. 100' to 150' mixed coarse and fine sand with silt lenses, over Cambrian and Ordovician SS and LS.	Low seasonal precipitation and net annual evaporation and very deep cross penetrations severely limit local recharge to the groundwater table. However, good hydraulic connections to nearby surface streams through very pervious subsoils have created a high-water table at the plant. The location of the bottom of the disposal pond at a depth of approximately six meters below the water table may create some flow anomalies and make interpretation of data from the site rather difficult. The existence of monitoring wells at the site, however, favors inclusion of this site in a monitoring effort. The possibility exists for cross flow between bedrock units and the pervious subsoils below the plant site at this location.

Table 3.7.4 (cont.)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Nelson Dewey, Wisconsin Power & Light/Grant County, WI, 42°42'30"N, 90°59'04" W (FA and BA to pond. All BA sold. On Mississippi River; 22 monitoring wells)	B+	34" avg. annual precip. (gross), -6" net; avg. annual temp. = 45°F, range -20° to 95°; frost penetration = 45" avg. per winter season. Below pond, 18' of sandy silt - silty sand, over 145' of sand and gravel over Ordovician limestone. Water table at 0 to 10' below surface. 20 year-old pond, 10' - 20' deep.	Low seasonal precipitation and net annual evaporation combine with deep frost penetration to limit local recharge to the groundwater system at this site. However, the water table is located at shallow depth because of good hydraulic connections between the subsoils under the site and nearby bodies of water. The generally pervious subsoils below the site should provide a good medium for monitoring of flow, and the existence of 22 monitoring wells at the site further favor inclusion of this plant in a monitoring effort. However, the existence of a pond bottom at a distance of more than three meters below the water table may complicate analysis of flow at the plant.
Oak Creek		Inadequate data for geotechnical evaluation.	
Port Washington		Inadequate data for geotechnical evaluation.	
Pulliam		Inadequate data for geotechnical evaluation.	
Valley		Inadequate data for geotechnical evaluation.	

3.7.4.2 Ratings

Table 3.7.5 presents the ratings for other site selection factors for the disposal operations in Region F. Methodology is discussed in Section 2.8 and discussion of individual plants is presented in Exhibit D.

3.7.5 Candidate and Back-up Sites

In Region F the targeted number of sites were:

- candidate sites: one or two,
- back-up sites: one.

Landfill and interim ponding/landfilling were prevalent disposal practices in this region. The investigation attempted to obtain a mix of sites keeping this in mind and noting selection in other regions. The recommended candidate and back-up sites are shown below:

Waste Type/Disposal Method	Candidate Sites	Back-Up Sites
Coal Ash		
Fly Ash/Pond (UL) Bottom Ash/Pond (UL)	Columbia I	--
Fly Ash/Landfill (UL) Bottom Ash/Interim Pond (ULAL); Landfill (UL)	Presque Isle	Huntley

Table 3.7.6 provides an overview on these sites' characteristics. A brief discussion of these sites follows.

Columbia I, Wisconsin Power & Light

Columbia I of Wisconsin Power & Light was designated as a candidate site. The disposal practice at this site was atypical of the region, however, it is an important disposal mode in that particular climate and setting. The outstanding advantages of the site included the presence of 19 groundwater monitoring wells, available studies on the ash ponds, no extraneous influents into the pond, and the tentative willingness of the utility to cooperate in the study. In addition, the soils underlying the site were expected to provide an excellent medium for groundwater flow monitoring and evaluation.

Table 3.7.5

OTHER SITE SELECTION RATINGS FOR DISPOSAL OPERATIONS IN THE GREAT LAKES REGION (REGION F)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. >7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Campbell, Consumer's Power	Combined Pond 3+	+	0	0	0	0	0	+	NA	0	0	0	+	NA	NA
Cobb, Consumer's Power	FA/BA Int. Pond 4+	+	0	+	0	0	0	+	NA	0	0	0	+	NA	NA
	FA/BA Fill 4+	+	0	+	0	0	0	+	NA	+	0	0	+	NA	-
Conner's Cr., Detroit Edison	FA/BA Int. Pond 1+	0	0	0	0	0	0	NA	NA	0	+	0	+	NA	-
	FA Fill 1+	0	0	0	0	0	0	+	0	+	0	0	+	NA	--
Eckert, Lansing Brd. of W&L	Combined Fill 2+	0	0	+	0	0	0	NA	NA	+	NA	NA	NA	NA	NA
Marysville, Detroit Edison	FA/BA Fill 1+	Same as St. Clair → 0	0	0	0	0	0	+	NA	0	0	0	+	+	—
	FA/BA Pond 1-	0	0	0	0	0	0	-	NA	0	0	0	+	+	—
Monroe, Detroit Edison	FA Pond 1+	0	0	0	0	0	0	-	NA	0	0	0	+	+	NA
	BA Pond 1+	0	0	0	0	0	0	+	NA	0	0	0	+	NA	-
Presque Isle, Upper Penn. Generating Company	BA Pond 3+	+	0	+	0	0	0	NA	NA	0	0	0	+	+	-
	FA/BA Fill 3+	+	0	+	0	0	0	NA	NA	+	0	0	+	NA	-
River Rouge, Detroit Edison	BA Int. Pond *	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	-
	FA/BA Fill 1+	Same as Conner's Creek → 0	0	0	0	0	0	+	0	+	0	0	+	NA	—

Table 3.7.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. ≥7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
St. Clair, Detroit Edison	BA Int. Pond 1+	0	0	0	0	0	0	+	NA	0	0	0	NA	NA	NA
	FA/BA Fill 1+	0	0	0	0	0	0	+	NA	0	0	0	+	+	—
Trenton Chan., Detroit Edison	FA/BA Int. Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	+	NA	NA
	FA/BA Fill 1+	Same as Conner's Creek → 0	0	0	0	0	0	+	0	+	0	0	+	NA	—
Whiting, Cons. Power	NA 1+	0	0	0	0	0	0	NA	NA	NA	NA	NA	+	NA	NA
Dunkirk, Niagra Mohawk	FA/BA Int. Pond 2+	0	0	+	0	0	0	NA	NA	0	0	0	+	+	-
	FA Fill 4+	0	0	+	0	0	0	-	+	+	0	0	++	+	-
Rochester #7, Rochester G&E Corp.	Retired BA Int. Pond 1+	0	0	0	0	0	0	NA	NA	0	0	0	NA	+	NA
	Retired Fills *	0	0	0	0	0	0	NA	NA	+	0	0	NA	NA	-
	New Fill *	0	0	0	0	0	0	-	NA	+	0	0	+	NA	-
Edgewater, WI P&L	Combined FA/BA Pond 6+	+	0	0	0	+	+	+	NA	0	0	0	++	NA	NA
Genoa #3, Dairyland Power Coop.	Combined FA/BA Pond 5+	+	0	+	0	0	0	+	NA	0	0	0	++ -	NA	NA
Nelson Dewey, WI P&L	Combined FA/BA Pond 4+	+	0	0	0	0	0	+	NA	0	0	0	++	NA	NA

Table 3.7, 5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. >7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Oak Creek, WI Electric Power	NA 4+	+	0	+	0	+	+	NA	NA	NA	NA	NA	NA	NA	NA
Pt. Washington, WI Electric Power	NA 4+	+	0	0	0	+	+	NA	NA	NA	NA	NA	+	NA	NA
Pulliam, WI Pub. Ser.	NA 4+	+	0	0	0	+	+	NA	NA	+	NA	NA	+	NA	NA
Valley, WI Electric Power	NA 7+	+	0	+	0	+	0	NA	NA	+	NA	NA	+	+	NA
Columbia I, WI P&L	FA Pond 6+	+	0	0	0	0	0	+	+	0	0	0	+	++	NA
	BA Pond 6+	+	0	0	0	0	0	+	+	0	0	0	+	++	NA
Huntley, Niagra Mohawk	BA Int. Pond 5+	+	0	NA	0	0	0	+	NA	0	+	0	+	+	NA
	FA/BA Fill 4+	+	0	NA	0	0	0	+	NA	+	0	0	+	+	-

Key:
NA = Information not available
0 = Not applicable
* = Sum of + and - is zero
ppt. = Precipitation
G.W. = Groundwater
S.W. = Surface water

Note: Rating methodology is described in Sec. 2.8; information on plants is summarized in Exhibit D.

Table 3.7.6

RECOMMENDED CANDIDATE AND BACK-UP SITES - GREAT LAKES REGION - REGION F

	Candidate	Background	Assessment of Disposal Operations	Geotechnical/Hydrogeologic Considerations	Other Factors
1	Columbia I Wisconsin Power and Light Portage County, WI	556-Mw plant started up in 1975. Fly and bottom ash disposal in separate unlined ponds.	Four year old ponds. Atypical disposal mode in region. 2+	Climate limits local recharge. Soils provide good medium for monitoring. A	Important disposal mode in climate and setting; baseline studies completed. 6+
2	Presquė Isle Upper Peninsula Generating Marquette County, MI	301-Mw plant started up in 1955. Fly ash to unlined landfill. Bottom ash to an unlined interim pond and then to an unlined landfill,	Closed cycle wet handling of bottom ash will be employed. Fly ash disposal mode typical in region. 3+	Climate limits total recharge. Igneous rocks may cause complication. C	Fly ash landfill in important area for climate and hence impacts; baseline data available. 3+
	Back-up				
3	Huntley Niagara Mohawk Power Erie County, NY	828-Mw plant started up in 1942. Fly ash disposal in an unlined landfill. Bottom ash to lined/unlined interim ponds and then to an unlined landfill.	Two of the four ponds are two years old. 3+	Climate limits local recharge. Bottom of disposal pond six meters below water table. Data interpretation could be complex. C	Important environmental setting and variety of disposal types. 4+ BA/FA landfill 5+ BA pond

Presque Isle, Upper Peninsula Generating

Presque Isle of Upper Peninsula Generating was designated as a candidate site. The disposal practice at this site was typical of the region. The outstanding advantages of this site included the fact that fly ash was handled dry and a closed-cycle wet handling system for bottom ash was to go in operation. Igneous bedrock below the site may limit the flow between bedrock units and subsoils, but subsurface data were inadequate for final evaluation at the time. The site is in an area of temperature extremes.

Huntley, Niagara Mohawk Power Corp.

Huntley of Niagara Mohawk Power Corp. was designated as a back-up site. The disposal practice at this site was typical of the region. The outstanding advantage of this site included the fact that fly ash was handled dry and two of the four ponds were lined, one with clay and the other with clay sides and a concrete bottom. Fine grained silty clay overlying shale bedrock, however, makes for very slow groundwater flow and therefore could cause monitoring to be difficult. The site is in an area of temperature extremes as is Presque Isle and was therefore a back-up to Presque Isle with respect to the landfilling of fly ash dry and the interim ponding followed by landfilling of bottom ash.

Some other sites considered interesting in this region (not in any special order) were:

- Dunkirk, Niagara Mohawk Power
- Genoa #3, Dairyland Power Corp.
- Valley, Wisconsin Electric Power

3.8 REGION G: SUPERIOR REGION

3.8.1 Background

The Superior Region includes all of Minnesota except the northeastern corner, the northeastern quarter of South Dakota, and the northeastern half of North Dakota.

As of 1977, this region had 17 coal-fired (greater than 80% of power generated from coal) power plants with a total capacity of 4780 Mw. Seven of these plants, with a combined capacity of 4280 Mw, had individual capacities of greater than 200 Mw and are considered further in this section. Table 3.8.1 summarizes the baseline data for these seven plants. These plants are generally located on or near the Mississippi River in Minnesota, with one plant located in South Dakota near the Minnesota border.

Plant generating capacities ranged from a low of 377 Mw to a high of 1440 Mw. Six of the plants fell in the 370 to 600 Mw range, with the remaining plant having a capacity of 1440 Mw. As of 1979, three plants had start-up dates* of less than 15 years prior, while the remaining four had start-up dates ranging anywhere from 22 to 49 years prior. The only operational FGD system in the region began operation in 1976.

Table 3.8.1

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN SUPERIOR REGION (G) OF THE U.S.

Plant Name	Utility Name	Capacity (Mw)[b,e] Nameplate Generating	Capacity (Mw)[b,e] FGD Scrubbed	State	County	Start-up Date Plant[c,d]	Start-up Date FGD[e]	Waste Type[f]	Disposal Method[e,f]
Black Dog*	Northern States Power	480	--	MN	Dakota	-/52	--	Fly Ash Comb. Fly & Bottom	Sold Interim Pond(UL); sold
Clay Boswell*	Minnesota Power & Light	514	--	MN	Itasca	-/58	--	Fly Ash Bottom Ash	Pond(CS) Pond(CS)
High Bridge*	Northern States Power	391	--	MN	Ramsey	-/42	--	Comb. Fly & Bottom	Sold
A.S. King*	Northern States Power	598	--	MN	Washington	-/68	--	Comb. Fly & Bottom	Landfill(UL)
Riverside*	Northern States Power	377	--	MN	Hennepin	-/31	--	Comb. Fly & Bottom	Landfill(UL)/sold
Sherburne County*	Northern States Power	1,440	1,440	MN	Sherburne	5/76	5/76	Fly/FGD Bottom Ash	Pond (AL) Interim Pond (AL); sold
Big Stone*	Otter Tail Power	440	--	SD	Grant	11/76	--	Fly Ash Bottom Ash	Landfill(UL) Interim Pond(CS); Landfill(UL)

Footnotes follow Table 3.1.1

The physiographic region and the prevailing climatic conditions are described in detail in Exhibit C. Average annual gross precipitation ranges from 50 cm (20 in.) in the Dakotas to 76 cm (30 in.) in southeastern Minnesota. Ambient temperatures for this region range from -43°C (-45°F) to 38°C (100°F), while the range of average temperatures is 2°C (36°F) to 7°C (45°F). These ambient temperatures testify to the severe winter conditions experienced in this region. Much of the region is flat glacial till, with occasionally morainic ridges. Large lacustrine clay deposits are also found in western Minnesota. Frost penetration ranges from about 102 to 127 cm (40 to 50 in.).

3.8.2 Assessment of Disposal Operations

3.8.2.1 Categorization of Disposal Operations

Table 3.8.2 presents a summary of waste disposal methods in Region G. The utility operations of the Superior Region employed two major disposal practices:

- ponding of coal ash and FGD waste, and
- dry landfilling of coal ash.

A general overview of the major types of disposal methods practiced in this region is presented below.

Disposal of Coal Ash and FGD Wastes in Ponds

Three plants in this region practiced single-step pond disposal of fly and bottom ash separately, with two of these plants selling some of their ponded ash. One plant practiced single-step pond disposal of combined fly and bottom ash. The Sherburne County plant was the only one in the region that employed an FGD system. In this plant, FGD wastes are co-disposed with fly ash in a pond.

Disposal of Coal Ash in Landfills

Two plants in this region practiced single-step landfilling of their coal ash. Riverside, even though it practiced landfilling, sold most of its ash in 1978 and thus offered a site with substantial waste variability. It was eliminated as a possible candidate site. The other plant, A.S. King, practiced dry landfilling of combined fly and bottom ash.

3.8.2.2 Assessment of Disposal Operations

Table 3.8.3 presents the results of the disposal operations assessment rating for Region G. The methodology employed in making this assessment is described in Section 2.6. Black Dog, High Bridge, and Riverside were

---

*Date on which coal became the primary source of fuel.

Table 3.8.2

MATRIX OF FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS

> 200 Mw IN THE SUPERIOR REGION (G) OF THE UNITED STATES IN 1979[a]

	Number of Plants		
Type of Waste	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	1	1	-
Bottom ash only	2	-	1
Combined fly and bottom ash	1	2	-
FGD waste only	-	-	-
Mixed fly ash and FGD waste	1	-	-
Mixed bottom ash and FGD waste	-	-	-
Mixed fly ash and FGD waste (stabilized)	-	-	-
Mixed fly ash, bottom ash, and FGD waste	-	-	-

---

[a] Coal-fired plants (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal.

Source: Compiled by Arthur D. Little, Inc. based on Utility Plant Data Survey Sheets used in developing Reference (1).

Table 3.8.3

ASSESSMENT OF DISPOSAL OPERATIONS IN SUPERIOR REGION (G) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Black Dog	X	1 1/2+	0	0	X	Most fly ash was sold in 1978.
Clay Boswell		1 1/2+	0	1/2+	2+	Extraneous pond influent is wastewater. Plant employs a wet particulate scrubber.
High Bridge	X	1 1/2+	0	1/2+	X	All ash was sold in 1978.
A.S. King		1 1/2+	0	1/2+	2+	Plant employs cyclone-fired boilers.
Riverside	X	1 1/2+	0	1/2+	X	Most ash was sold in 1978.
Sherburne County		1 1/2+	1+	1+	3 1/2+	Fly ash and FGD ponded together. Pond is 4 years old.
Big Stone		1 1/2+	0	1+	2 1/2+	Pond and landfill are 4 years old. Plant employs a cyclone-fired boiler.

---

[a] Assessment rating system explained in Section 2.6.

all eliminated from further consideration due to their selling of ash. Sherburne County rated quite highly since it employs an FGD system and practices water recycle and co-disposal. The rest of the plants (Clay Boswell, A.S. King, and Big Stone) in this region also warranted further evaluation. The hydrogeologic and other site selection factor ratings of these plants provided the discrimination necessary for the selection of the candidate sites.

3.8.2.3 Comments on Handling and Transportation of FGC Wastes

Ponding was one of the dominant practices in this region. Conventional handling of slurries was typical; most, if not all, impoundments were on-site and the designs followed conventional practices. The A.S. King plant practiced dry handling of its fly and bottom ash which is a potential practice for the future in this region due to limited water availability.

3.8.3 Geotechnical and Hydrogeologic Considerations

Table 3.8.4 presents an evaluation of geotechnical and hydrogeologic considerations and subsequent ratings for the sites in Region G. The methodology employed in making this assessment is presented in Section 2.7. Sherburne County had the most desirable hydrogeologic and geotechnical conditions. The rest of the plants evaluated in the region have very similar hydrogeologic and geotechnical conditions.

3.8.4 Other Site Selection Considerations

In general, this is a region of temperature extremes. All the plants considered were located in areas that experienced >7000 degree days and <150 frost-free days annually. The region experienced 40 to 75 cm (16 to 30 in.) of precipitation per year.

Table 3.8.5 presents the ratings for other site selection considerations for disposal operations in Region G. The rating methodology is described in Section 2.8 and the individual plant information is presented in Exhibit D.

3.8.5 Candidate and Back-Up Sites

In Region G the targeted numbers of sites were:

- candidate sites: one or two;
- back-up sites: up to one.

Details on the assessments from engineering/technological, hydrogeologic and other site selection factor viewpoints were presented in Tables 3.8.2 through 3.8.5. Taking all of these into account, the investigators evaluated the more promising sites to arrive at recommendations. Since this region practiced dry handling of coal ash and FGD ponding, primary effort focused on

Table 3.8.4

GEOTECHNICAL/HYDROGEOLOGIC RATING OF SITES - REGION G

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Black Dog - Northern States Power/Dakota County, MN, 44°-49'-31" N, 93°-13'-58" W (15 miles SW of Minneapolis) (BA/FA [8/92] pond; 84% FA sold; no data on landfill offsite)	C	30" avg. annual precip. (gross), -15" net; avg. annual temp. = 40°F, range -30° to 95°; frost penetration = 50" per winter season. Lower Paleozoic continental sedimentary bedrock, overlain by glacial drift. Depth of pond is 10'; water at <10'.	Very low seasonal precipitation with high net annual evaporation and deep cross penetration severely limit local recharge to the groundwater system at the plant site. The glacial soils beneath the site should provide for very slow and possibly erratic flow conditions. The existence of a water table above the bottom of the disposal pond at the site may complicate analysis. The existence of an offsite landfill may further complicate the investigation.
Clay Boswell - Minnesota Power and Light/Itasca County, MN, 47°-15'-40" N, 93°-39'-26" W (separate lined ponds BA/FA [47/49]; 21 monitoring wells around pond) (near Hibbing, MN, in Grand Rapids, MN)	C+	28" avg. annual precip. (gross), 4" net; avg. annual temp. = 40°F, range -40° to 95°; frost penetration = 50" per winter season. 2' of fat clay over 3' sandy silt below pond. 18'-20' deep pond; 4' to water table. Metamorphic PreCambrian bedrock overlain by thick glacial drift (till plain with moraine deposits).	Low net annual precipitation and low seasonal rainfall combined with deep frost penetration during winter months to limit local infiltration in recharge to the groundwater flow system. The presence of a very slowly pervious clay soil below the disposal pond with more pervious soil beneath the clay may make for very complicated flow conditions, particularly since the possibility exists for cross flow between the bedrock and the subsoils. The existence of a water table more than five meters above the bottom of the disposal pond may further complicate interpretation of monitoring results. The presence of 21 monitoring wells around the pond may not balance the unfavorable conditions previously noted.
High Bridge - Northern States Power/Ramsey County, MN (FA and BA sold [100%] for airfield construction)		28" avg. annual precip. (gross), -8" net; avg. annual temp. - 40°F, range -30° to 95°; frost penetration = 50" per winter season.	The geotechnical conditions at this plant site were not evaluated since all of the waste products from this plant are sold and are not disposed on site.
A. S. King - Northern States Power/Washington County, MN, (15% ash sold; combined BA/FA landfill; landfill in Oak Park Heights, MN) (near St. Paul)	C	28" avg. annual precip. (gross); -8" net; avg. annual temp. = 40°F, range -40° to 95°; frost penetration = 50" per winter season. Bedrock is Jordan SS, massive SS, over shaley and sandy dolomite over thinly bedded SS (St. Croix Series, Cambrian Age). Subsoils are 12.5' silty clayey sand (SM, SC) underlain by 6' poorly graded sand (SP), underlain by sandstone. Landfill is 60' deep. Water table is at 10'.	Low seasonal precipitation and net annual evaporation combined with very deep frost penetration to limit local recharge to groundwater resources at the plant site. Surficial soils consisting of clayey sands underlain by sandstone constitute conditions for very erratic flow and could create a situation very difficult if not impossible to monitor and evaluate. Very significant possibilities exist for cross flow between the sandstone bedrock and the overlying sand soils. The presence of the water table at the plant site at a relatively shallow depth indicates adequate flow through the clean sandy soils, but this flow may originate in the bedrock units and the net flow system at the plant site may consist of in-flow from the bedrock into the disposal area.

Table 3.8.4 (cont)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Riverside - Northern States Power/Hennepin County, MN, (Combined FA/BA landfill; 70% sold)	C-	28" avg. annual precip. (gross), -8" net; avg. annual temp. = 40°F, range -40° to 95°; frost penetration = 50" per winter season. 20' to water table. Subsoils are 2' of clayey (fill) sand (SC), 4.5' of mixed fill, over 22' of low plasticity clay (CL) over silty sand. Alluvium. Paleozoic SS, Sh bedrock.	Low seasonal precipitation with net annual evaporation and very deep frost penetration combined to severely inhibit local recharge of groundwater resources around the plant site. The existence of mixed fill over very low permeability clay soils over high permeability sands above bedrock should create an extremely complex flow system and a flow medium which may alter the chemistry of the groundwater and of any leachate coming from the disposal area. This system may be almost impossible to monitor and evaluate.
Sherburne County - Northern States Power/Sherburne County, MN, 45°-22'-45" N, 93°-53'-44" W (Eight monitoring wells) (City of Becker, near St. Cloud, MN, near Mississippi River)	A-	28" avg. annual precip. (gross), -12" net; avg. annual temp. = 45°F, range -30° to 95°; frost penetration = 50° per winter season. Silty sand and clean sand (SM to SP) to weathered granite at 80'. Below FA/FGD pond, 25' to water table. 18" clay liner for FA/FGD pond.	Low seasonal precipitation and high net annual evaporation limit recharge to the groundwater resources at the site. Deep frost penetration would prevent any infiltration during winter months. Regional groundwater flow, probably dominated by the Mississippi River, would predominate at the site. Sandy soils above granite bedrock should provide a good medium for monitoring and evaluation of flow conditions. This site provides an opportunity to measure the effectiveness of a clay liner below the fly ash and FGD pond. The existence of eight monitoring wells at the site also favor inclusion of this plant in the monitoring and evaluation effort.
Big Stone - Otter Tail Power Company/Grant County, SD, 45°-18'-17" N, 96°-30'-30" W (BA pond LF; FA LF) (Big Stone City)	C	22" avg. annual precip. (gross), -12" net; avg. annual temp. = 45°F, range -30° to 100°; frost penetration = 40" per winter season. Interim pond is 23' deep, with water more than 120' below pond. Below pond, layers of clay and sandy clay to 121'. Landfill is 20'-25' thick with water table at more than 144' below the surface. Below LF, silty clay and sandy clay layers to 133', sand and gravel from 133' to 144'. Metamorphic bedrock at great depth.	Very low seasonal precipitation and net annual evaporation combined with deep frost penetration to limit local recharge to the groundwater system. Water is found at more than 40 meters below the pond at the plant site. Subsoils consisting of clays and sandy clays would make for very slow and very difficult to monitor groundwater flow.

Table 3.8.5

OTHER SITE SELECTION RATINGS FOR DISPOSAL OPERATIONS IN THE SUPERIOR REGION (REGION G)

Plant & Utility	Total Rating (+ and -)	REGIONAL/GENERIC FACTORS: Climate						SITE-SPECIFIC FACTORS: Setting		Mitigative Controls					
		Temp. >7000 Degree Days F (+)	ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	Water Use G.W. (+)	Water Use S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
Black Dog, North. Sts. Power Co.	FA/BA Int. Pond 3+	+	0	+	0	0	0	NA	NA	0	0	0	+	NA	NA
Clay Boswell, MN P&L	FA Pond 4+	+	0	+	0	0	0	+	NA	0	0	0	++	NA	-
	BA Pond 4+	+	0	+	0	0	0	+	NA	0	0	0	++	NA	-
High Bridge, North Sts. Power Co.	NA 2+	+	0	+	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
A.S. King, North. Sts. Power Co.	FA/BA Fill 5+	+	0	+	0	0	0	+	NA	+	0	0	+	NA	NA
Riverside, North. Sts. Power Co.	FA/BA Fill 5+	+	0	+	0	0	0	NA	0	+	0	0	+	+	NA
Sherburne Co., North. Sts. Power Co.	FA/FGD Pond 8+	+	0	+	0	0	0	+	+	0	+	0	+	++	NA
	BA Pond 2+	+	0	+	0	0	0	NA	NA	0	NA	0	NA	NA	NA
Big Stone, Otter Tail Power Co.	FA/BA Int. Pond 2+	+	0	+	0	0	0	-	NA	0	0	0	NA	+	NA
	FA/BA Fill 2+	+	0	+	0	0	0	-	NA	+	0	0	+	NA	-

Key:
NA = Information not available
0 = Not applicable
* = Sum of + and - is zero
ppt. = Precipitation
G.W. = Groundwater
S.W. = Surface water

Reproduced from best available copy.

Note: Rating methodology is described in Sec. 2.8; information on plants is summarized in Exhibit D.

selecting the most suitable candidates for these modes. The recommended candidate sites are:

Waste Type/ Disposal Method	Candidate Sites
Coal Ash	
Combined Fly and Bottom Ash/ Landfill (UL)	A.S. King
FGD Wastes	
Fly and FGD Waste/Pond (CS) Bottom Ash/Interim Pond; Sold	Sherburne County

Note: No back-up sites were recommended.

Table 3.8.6 provides an overview of these sites' characteristics. A brief description of these sites follows.

A.S. King, Northern States Power Company

The A.S. King plant of Northern States Power Company was designated as a candidate site. The plant employed cyclone-fired boilers which would offer the opportunity to evaluate a landfill where the ratio of bottom ash to fly ash is more equal than that from pulverized coal-fired boilers. The disposal practice at this site was considered to be typical for this region. The use of dry fly and bottom ash handling was of special interest due to the expected trends toward dry ash handling. Other site selection factors at this site rated favorably.

Table 3.8.6

RECOMMENDED CANDIDATE AND BACK-UP SITES - SUPERIOR - REGION G

Candidate	Description	Assessment of Disposal Operations	Geotechnical/Hydrogeologic Considerations	Other Factors
1 A.S. King Plant Northern States Power Washington County, MN	598-Mw plant started up in 1968. Combined fly and bottom ash disposed in an unlined landfill.	Landfill disposal has future potential, employs dry ash handling.	Net evaporation and deep frost penetration limit local recharge to groundwater. Sandy and silty soils.	
		2+	C	5+
2 Sherburne County Northern States Power Sherburne County, MN	1,440-Mw plant started up in 1976. Fly ash and FGD co-disposed in a lined pond. Bottom ash disposed in lined interim pond and then sold.	Co-disposal of FGD and fly ash to lined pond potentially important for future assessment efforts.	This site provides an opportunity to measure the effectiveness of clay liner on FGD and fly ash pond. Sandy soil above granite bedrock should provide good medium for monitoring.	
		3 1/2+	A-	8+ (Fly ash/ FGD pond) 2+ (Bottom ash pond)

No back-up site in region

Sherburne County, Northern States Power Company

Sherburne County of Northern States Power Company has been tentatively designated as a candidate site because it employs the only FGD system in the Superior Region, as well as receiving extremely high hydrogeologic and other site selection factor ratings. These high ratings are primarily due to the fact that the ponds are set on sandy soil above granite bedrock which would provide a good medium for monitoring and evaluation of flow conditions. The site also provides an opportunity to measure the effectiveness of a clay substrate liner below a fly ash and FGD pond.

3.9 REGIONS H-M: GREAT PLAINS AND WEST REGION

3.9.1 Background

The Great Plains and West Region includes Regions H, I, J, K, L, and M. This large area includes the western half of Texas, most of Oklahoma, Kansas, Nebraska, western and central South Dakota, the southwestern half of North Dakota, and all of the eleven contiguous states located west of these.

As of 1977, this region had 45 coal-fired (greater than 80% of power generated from coal) power plants with a total capacity of 26,102 Mw.* Thirty-one of these plants, with a capacity of 24,696 Mw had individual capacities of greater than 200 Mw and are considered further in this section. Table 3.9.1 summarizes the baseline data for these 31 plants. These plants are generally located (a) in the Great Plains, from Texas to North Dakota and southeastern Montana; (b) in the Rocky Mountain region from Arizona to Wyoming; and (c) in the Great Basin in Arizona and Nevada. One plant is located in the State of Washington.

Plant generating capacities ranged from a low of 212 Mw to a high of 2409 Mw. Twenty-five of the plants fell in the 200 to 1000 Mw range, while the other six were between 1300 and 2500 Mw. In 1979, thirteen plants had start-up dates** of less than 10 years prior. Eleven plants started up 10 to 20 years prior. The remaining seven plants began operation 20 to 41 years prior. Of the 13 operational FGD systems in the region, seven had been operating for under two and one-half years. The others ranged in operating time from four to nine years.

The physiographic region and the prevailing climatic conditions are described in detail in Exhibit C. This large region is characterized more by internal contrast than by uniformity. Average annual gross precipitation ranges from 25 to 254 cm (10 to 100 in.), but is generally low over much of this region. Ambient temperatures for this region range from -40° to 43°C (-40° to 109°F), while the average annual temperatures range from 2° to 21°C (36° to 70°F). The region contains a broad range

---

* Includes plants that were <80% coal-fired in 1977 because they employed FGD systems.

** Date on which coal became the primary source of fuel.

Table 3.9.1

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN GREAT PLAINS AND WEST REGIONS (H THROUGH M) OF THE U.S.

Plant Name	Utility Name	Capacity (Mw)[b,e] Nameplate Generating	Capacity (Mw)[b,e] FGD Scrubbed	State	County	Start-up Date Plant[c,d]	Start-up Date FGD[e]	Waste Type[f]	Disposal Method[e,f]
					REGION H: SOUTHERN PLAINS				
Comanche*	Public Service of Colorado	778	--	CO	Pueblo	-/73	--	Fly Ash Bottom Ash	Landfill(?) Interim Pond(?); Landfill(?)
Jeffrey	Kansas Power & Light	720	540	KS	Pottawatomie	6/78	8/78	Fly Ash Bottom/FGD	? Pond(L)
La Cygne	Kansas City Power & Light	1,558	874	KS	Linn	-/73	6/73	Fly/FGD Bottom Ash	Pond(UL) Pond(UL)
Lawrence[j]	Kansas Power & Light	613	545	KS	Douglas	-/39	11/71	NA	NA
Asbury	Empire District Electric	212	--	MO	Jasper	-/70	--	NA	NA
Hawthorn[j]	Kansas City Power & Light	908	180	MO	Jackson	-/51	8/72	Fly/FGD Bottom Ash	Pond(UL) Pond(UL)
Montrose	Kansas City Power & Light	563	--	MO	Henry	-/58	--	NA	NA
Harrington	Southwestern Public Ser.	360	--	TX	Potter	8/76	--	NA	NA
					REGION I: NORTHERN PLAINS				
Colstrip*	Montana Power	720	720	MT	Rosebud	11/75	11/75	Fly/FGD Bottom Ash	Interim Pond(CS); Pond(UL) Interim Pond(CS); Pond(UL)
North Omaha Station*	Omaha Public Power Dist.	644	--	NE	Douglas	-/54	--	Fly Ash Bottom Ash	Landfill(UL)/sold Hydrobin; Landfill(UL)/sold
Sheldon Station*	Nebraska Public Power Dist.	228	--	NE	Lancaster	-/61	--	Comb. Fly & Bottom	Hydrobin; Landfill(UL)
Coal Creek	Cooperative Power Assoc.	550	327	ND	McLean	5/79	7/79	NA	NA
Leland Olds*	Basin Electric Power Coop.	656	--	ND	Mercer	1/66	--	Comb. Fly & Bottom	Pond(UL)
Young*	Minnkota Power Coop.	673	405	ND	Oliver	11/70	6/78	Fly Ash Fly/FGD Bottom Ash	Landfill(mine) Landfill(mine) Hydrobin; Landfill(mine)
Dave Johnston*	Pacific Power & Light	750	--	WY	Converse	-/59	--	Comb. Fly (scrubber) & Bottom Fly Ash Bottom Ash	Interim Pond(CS); Landfill(UL) Landfill(UL) Interim Pond(UL); Landfill(UL)

Table 3.9.1 (continued)

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN GREAT PLAINS AND WEST REGIONS (H THROUGH M) OF THE U.S.

REGION J: ROCKY MOUNTAIN

Plant Name	Utility Name	Capacity (Mw)[b,e]		State	County	Start-up Date		Waste Type[f]	Disposal Method[e,f]
		Nameplate Generating	FGD Scrubbed			Plant[c,d]	FGD[e]		
Cholla[i]	Arizona Public Ser.	469	469	AZ	Navajo	-/62	10/73	Fly Ash Fly/FGD Bottom Ash	Sold Pond(UL) Pond(?)
Navajo	Salt River Project	2,409	--	AZ	Coconino	5/74	--	NA	NA
Arapahoe*	Public Service of Colorado	250	--	CO	Denver	-/50	--	Comb. Fly & Bottom	Interim Pond(?); Landfill(?)
Cherokee*	Public Service of Colorado	801	--	CO	Adams	-/57	--	Fly Ash Bottom Ash	Landfill(AL) Interim Pond(?); Landfill(AL)
Drake*	Colorado Springs Dept. Public Utilities	282	--	CO	El Paso	-/62	--	Comb. Fly & Bottom	Hydrobin; Landfill(CS)
Hayden Station*	Colorado Utilities Electric Assoc.	465	--	CO	Routt	7/65	--	Comb. Fly & Bottom	Landfill(UL)
Four Corners	Arizona Public Ser.	2,269	--	NM	San Juan	-/63	--	Fly Ash Bottom Ash	Interim Pond(?); Landfill(?) Pond(?)
San Juan*	Public Service of New Mexico	711	711	NM	San Juan	11/73	4/78	Fly Ash Bottom Ash	Landfill (mine) Hydrobin; Landfill (mine)
Hunter*	Utah Power & Light	400	360	UT	Emery	6/78	5/79	Fly/FGD/Bottom	Landfill(UL)
Huntington*	Utah Power & Light	705	366	UT	Emery	-/74	5/78	Fly/FGD Bottom Ash	Landfill(UL) Hydrobin; Landfill(UL)
Jim Bridger*	Pacific Power & Light	1,525	--	WY	Sweetwater	9/7	--	Comb. Fly & Bottom	Landfill(mine)
Naughton	Utah Power & Light	707	--	WY	Lincoln	-/63	--	NA	NA
				REGION K: GREAT BASIN					
Apache*[i]	Arizona Electric Power Coop.	465	390	AZ	Cochise	9/64	1/79	Fly/Bottom/FGD	Pond(UL)
Gardner*	Nevada Power	340	340	NV	Clark	-/65	4/74	Fly Ash Comb. Fly & Bottom FGD	Sold Landfill(UL) Pond(UL)
Mohave*	Southern California Edison	1,636	--	NV	Clark	4/71	--	Comb. Fly & Bottom	Landfill(UL)

Table 3.9.1 (concluded)

PRELIMINARY LISTING OF POTENTIAL POWER PLANT[a] SITES IN GREAT PLAINS AND WEST REGIONS (H THROUGH M) OF THE U.S.

REGION L: COLUMBIA PLATEAU

No plants within this region.

REGION M: PACIFIC COASTAL

Plant Name	Utility Name	Capacity (Mw)[b,e] Nameplate Generating	FGD Scrubbed	State	County	Start-up Date Plant[c,d]	FGD[e]	Waste Type[f]	Disposal Method[e,f]
Centralia*	Pacific Power & Light	1,329	--	WA	Lewis	-/72	--	Comb. Fly & Bottom	Interim Pond(UL); Landfill(mine)

of topography and soil conditions. Frost penetration ranges from insignificant in southern California to over 102 cm (40 in.) in northern Montana.

3.9.2 Assessment of Disposal Operations

3.9.2.1 Categorization of Disposal Operations

T 392

Table 3.9.2 presents summary data on disposal methods in Regions H-M. The utility operations of the Great Plains and the West typically employed one or more of all three basic disposal practices for fly ash, bottom ash, and FGD waste:

- single-step landfill disposal of fly ash,
- single-step pond disposal of bottom ash,
- single-step landfill disposal of combined fly and bottom ash,
- interim pond followed by landfill disposal of coal ash, and
- single-step pond disposal of FGD waste co-disposed with fly ash.

Against the background of the national trend toward FGC waste disposal in managed fills, it appeared that direct landfill or interim ponding followed by landfilling will be major disposal options in the region. Dry FGD scrubbers were also expected to grow in importance in this region, adding to the trend toward landfilling as a disposal option.

The West is a region where the use of FGD systems was expected to grow by a relatively large factor (see Table 2.4.7) emphasizing the need to investigate FGD disposal under western environmental conditions. The major disposal methods for FGC wastes in this region are discussed below.

Disposal of Fly Ash, Bottom Ash, and FGD Waste in Landfills

Fourteen of the plants listed in this region on which the investigators had data reportedly used single-step landfill disposal for at least one of their major solid wastes. Combined fly and bottom ash landfilling was practiced at Sheldon Station, Drake, Hayden Station, Jim Bridger (mine), Gardner, and Mohave. Fly ash landfilling was employed at Comanche, North Omaha Station, Young (mine), Dave Johnston, Cherokee, and San Juan (mine). Combined fly ash and FGD waste landfilling was practiced at Young (mine) and Huntington. Bottom ash landfilling was practiced at North Omaha Station, Young (mine), and San Juan (mine). Combined fly ash, bottom ash and FGD waste landfilling was practiced at Hunter.

Disposal of Fly Ash and Bottom Ash in Interim Ponds/Landfills

Interim ponding followed by ultimate landfilling of the waste is another common practice for coal ash. At least seven plants in this region followed this practice. Combined fly and bottom ash interim ponding followed by

Table 3.9.2

MATRIX OF FGC WASTE DISPOSAL METHODS UTILIZED AT UTILITY COAL-FIRED POWER PLANTS ≥ 200 Mw IN THE GREAT PLAINS AND WEST REGIONS (H-M) OF THE UNITED STATES IN 1979[a]

Type of Waste	Number of Plants		
	Pond[b]	Landfill[c]	Interim Pond/Landfill[c]
Fly ash only	-	6	1
Bottom ash only	5	4	3
Combined fly and bottom ash	1	6	3
FGD waste only	1	-	-
Mixed fly ash and FGD waste	4	2	-
Mixed bottom ash and FGD waste	1	-	-
Mixed fly ash and FGD waste (stabilized)	-	-	-
Mixed fly ash, bottom ash, and FGD waste	1	1	-

---

[a] Coal-fired plants (≥ 80% of their power generated from coal in 1977) which have generating capacities ≥ 200 Mw with the exception of four plants employing FGD systems. Figures represent the number of plants at which each waste type/disposal method is practiced. (Note: many plants utilize more than one method.)

[b] Includes direct ponding and interim/final ponding methods.

[c] Includes managed and unmanaged fills and mine disposal.

Source: Compiled by Arthur D. Little, Inc. based on Utility Plant Data Survey Sheets used in developing Reference (1).

landfill was practiced at Dave Johnston, Arapahoe, and Centralia. Bottom ash interim ponding followed by landfill was employed at Comanche, Dave Johnston, Cherokee, and Huntington, while fly ash interim ponding follwed by landfill was practiced at Four Corners.

Disposal of Fly Ash, Bottom Ash, and FGD Waste in Ponds

Ponding is not as prevalent a practice in this region as in the east. The relative scarcity of water has helped lead to the use of other methods of disposal. Some ponding is practiced, particularly for bottom ash. Combined fly and bottom ash ponding was practiced at Leland Olds. Separate bottom ash ponding was employed at LaCygne, Hawthorn, Colstrip, Cholla, and Four Corners. Mixed fly ash and FGD waste ponding was practiced at LaCygne, Hawthorn, Colstrip, and Cholla. Mixed bottom ash and FGD waste ponding was practiced at Jeffrey. FGD waste was ponded separately at Gardner. Combined fly and bottom ash co-disposed with FGD waste was ponded at Apache. Mixed fly ash/FGD waste interim ponding followed by final ponding is an unusual practice and was employed at Colstrip.

3.9.2.2 Assessment of Disposal Operations

Table 3.9.3 presents the results of the disposal operation assessment rating for Regions H-M. The methodology employed in making this assessment is described in Section 2.6. Several plants warranted further evaluation based on the disposal operation perspective. These included Comanche, Jeffrey, LaCygne, Hawthorn, Colstrip, Young, Dave Johnston, Arapahoe, Drake, Hayden Station, Four Corners, Huntington, Jim Bridger, and Mohave. Seven plants (North Omaha Station, Coal Creek, Cholla, Cherokee, Hunter, Apache, and Gardner) were eliminated from further consideration due to the disposal site being less than two years old and/or the fact that the majority of the plant's coal ash had been sold in recent years. Hydrogeologic and other site selection factor ratings narrowed the field considerably.

3.9.2.3 Comments on Handling and Transportation of FGC Wastes

On-site disposal of FGC wastes is usually practiced in this region, but plant locations are often in the less populated areas of the region and off-site disposal can involve transporting the waste significant distances. In this area, the transport of moist FGC wastes by truck was relatively more important than pumping of FGC slurries.

3.9.3 Geotechnical and Hydrogeologic Considerations

Table 3.9.4 presents and evaluation of the geotechnical and hydrogeologic considerations and subsequent ratings for the sites in Regions H-M. The methodology employed in making this assessment is discussed in Section 2.7.

Table 3.9.3

ASSESSMENT OF DISPOSAL OPERATIONS IN GREAT PLAINS & WEST REGION (II-M) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Comanche		1 1/2+	1+	1/2+	3+	
Jeffrey		1 1/2+	1+	1+	3 1/2+	Plant and FGD system are 2 years old.
La Cygne		1 1/2+	2+	1/2+	4+	
Lawrence		1 1/2+	1+	NA	NA	
Asbury		1/2+	NA	NA	NA	
Hawthorne		1 1/2+	2+	1/2+	4+	Plant was < 80% coal-fired in 1977.
Montrose		1 1/2+	NA	NA	NA	
Harrington		1/2+	NA	NA	NA	Plant employs a wet particulate scrubber.
Colstrip		1 1/2+	2+	1/2+	4+	
N. Omaha Sta.	X	1 1/2+	1+	1/2+	X	All ash was sold in 1978.
Sheldon Station		1 1/2+	1+	1/2+	3+	Landfill is two years old.
Coal Creek	X	1+	0	NA	X	Plant and FGD system < 2 years old.
Leland Olds		1 1/2+	0	0	1 1/2+	Retired pond has been reopened and is being used as a landfill.
Young		1 1/2+	2+	1/2+	4+	Landfill is a mine.
Dave Johnston		1 1/2+	1+	1+	3 1/2+	Municipal plant waste is landfilled with coal ash. Plant employs a wet particulate scrubber.
Cholla	X	1 1/2+	2+	1/2+	X	Unit 1 (110 Mw) in operation for 18 years. Unit 2 (250 Mw) in operation for 2 years. Retired pond is 16 years old. New pond < 2 years.
Navajo		1 1/2+	NA	NA	NA	
Arapahoe		1 1/2+	0	0	1 1/2+	Landfills were once used. Plant employs a wet particulate scrubber.
Cherokee	X	1 1/2+	1+	1/2+	X	Plant employs a wet particulate scrubber. Landfill < 2 years old. Landfill is lined with bentonite.
Drake		1 1/2+	1+	1+	3 1/2+	Landfill is 2 years old.
Hayden Station		1 1/2+	1+	1/2+	3+	
Four Corners		1 1/2+	1+	0	2 1/2+	Plant employs a wet particulate scrubber.
San Juan		1 1/2+	2+	1/2+	4+	FGD is a recovery process. Landfill is a mine.

Table 3.9.3 (continued)

ASSESSMENT OF DISPOSAL OPERATIONS IN GREAT PLAINS & WEST REGION (H-M) OF THE UNITED STATES[a]

	Elimination Criteria	Rating Criteria				
Plant Name	Ash Selling/Site Age	Waste Variability Considerations	Disposal Practices	Mitigative Engineering Practices	Total	Comments
Hunter	X	1 1/2+	0	1/2+	X	FGD system < 2 years old.
Huntington		1 1/2+	1+	1/2+	3+	
Jim Bridger		1 1/2+	1+	1/2+	3+	Landfill is a coal mine. FGD system under construction.
Naughton		1 1/2+	NA	NA	NA	Plant personnel feel their site has already been overstudied.
Apache	X	1+	0	1+	X	Pond and FGD system < 2 years old.
Gardener	X	1 1/2+	2+	0	X	FGD waste is ponded separately. Landfill is 3 years old. Majority of fly ash was sold in 1978.
Mohave		1 1/2+	1+	1/2+	3+	Coal transport to plant by pipeline.
Centralia		1 1/2+	0	0	1 1/2+	Landfill is a coal mine.

---

[a] Assessment rating system explained in Section 2.6.

Table 3.9.4

GEOTECHNICAL/HYDROGEOLOGIC RATING OF SITES - REGIONS H - M

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Comanche - Public Service of Colorado/Pueblo County, CO (at junction of Arkansas and Saint Charles Rivers)	B+	12-15" avg. annual precip. (gross), -36" net; avg. annual temp. = 50°F, range -20° to 90°; frost penetration = 10 - 15". Cretaceous sedimentary formations; mostly sandstones and shales; thin sandy surficial deposits; perhaps sandy alluvium near Arkansas River; just east of ROCKY MOUNTAIN REGION and SOUTHERN PLAINS REGION.	Net evaporation, but seasonal precipitation, with only shallow frost penetration, make for limited infiltration. However, regional flow near river junction should be significant. Alluvium over sandstone and shale rock units should provide medium for flow monitoring and analysis.
Jeffrey		Inadequate data for geotechnical evaluation.	
La Cygne		Inadequate data for geotechnical evaluation.	
Lawrence		Inadequate data for geotechnical evaluation.	
Asbury		Inadequate data for geotechnical evaluation.	
Hawthorne		Inadequate data for geotechnical evaluation.	
Montrose		Inadequate data for geotechnical evaluation.	

Table 3.9.4 (cont.)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Harrington		Inadequate data for geotechnical evaluation.	
Colstrip - Montana Power/Rosebud County, Colstrip, MT (90 miles E. of Billings) (FGD)	B+	14" avg. annual precip. (gross), -30" net; avg. annual temp. = 40°F, range -30° to 100°; frost penetration = 30". Tertiary sandstones, conglomerates with some shales; thin stony surficial deposits; NORTHERN PLAINS REGION.	Thin stony soil deposits over interbedded sandstones and shales make for complex flow patterns, difficult to evaluate. Net evaporation and significant frost action limit local recharge so groundwater flow may be deep in rock. Mine environment may simplify flow regime.
North Omaha Station - Omaha Public Power District/Douglas County, NE (FA all sold; BA dewatered, then sold)	C	28" avg. annual precip. (gross), -12" net; avg. annual temp. = 50°F, range -20° to 105°; frost penetration = 20" avg. per winter season. Pond for water from bottom ash and coal pile runoff. Below pond, 3 feet of fly ash over 12 feet of "alluvial clay". Water table 12' below bottom of pond. Upper Paleozoic sedimentary bedrock below soils developed from loess and Mississippi River alluvium.	Disposal operations at this site are limited to interim ponding of bottom ash in a facility which is underlain by one meter of fly ash over more than three meters of clay. Sedimentary bedrock units underly this sequence. This site would be very difficult to monitor and water quality measurements on samples from this site would be very difficult to evaluate.
Sheldon Station - Nebraska Public Service District/ Lancaster County, NB, 40°33'32" N, 96°47'04" W (FA/BA interim pond, then LF)	C	26.7" avg. annual precip. (gross), -17.3" net; avg. annual temp. = 50°F, range -20° to 105°; frost penetration = 20" per winter season. Below interim pond, 30' silty clay loam over 18' clay loam over 7' silty clay loam. Pond is 17' deep; water table is at 72' below surface. Below landfill, water table is at 128'. Below storage area, 68' clay over 1' sand over 10' clay over 7' gravel over 25'clay over 20' sand over 8' sandy clay over 43' sand & gravel. Below LF, 101'clay over 25' sand over 38' clay; water table at 128'.	A very thick sequence of clay layers interspersed with sand and gravel layers underly the disposal facilities for this plant. The water table at the interim pond and at the landfill site is very deep. Very low seasonal precipitation and net annual evaporation combine to severely limit local recharge to the groundwater flow system. Evaluation of flow conditions at this site would be very difficult.
Coal Creek		Inadequate data for geotechnical evaluation.	
Leland Olds		Inadequate data for geotechnical evaluation.	

Table 3.9.4 (cont.)

Note: Ratings described in Section 2.7.

Plant/Location	Rating	Background	Comments
Young - Minnkota Power/Oliver County, ND		Inadequate data for geotechnical evaluation.	
Dave Johnston - Pacific Power & Light/Converse County, Glenrock, WY (near Casper); (Region H, very near Region J)	B+	15" avg. annual precip. (gross), -30.5" net; avg. annual temp. = 40°F, range -20° to 95°; frost penetration = 20". Cretaceous sandstones and shales; thin stony surficial deposits except for sandy alluvium near Platte River. BORDER NORTHERN REGION and ROCKY MOUNTAIN REGION (Wyoming Basin).	Thin stony soils over sedimentary bedrock severely constrain monitoring activities; local stream alluvium may provide medium for monitoring flow system. Significant frost action impedes winter infiltration. Seasonal precipitation and high net evaporation limit local recharge, so flow may be deep within rock units.
Cholla - Arizona Public Service/Joseph City County, AZ (Region J) (FGD also)	B	10" avg. annual precip. (gross), -30" net; avg. annual temp. = 50°F, range -20° to 100°; frost not a factor. Triassic-Jurassic conglomerates, sandstones, thin desert sandy soils.	Thin pervious sandy soils over sandstones and conglomerates should provide flow milieu capable of analysis. Arid climate with net evaporation will seriously constrain groundwater recharge, although leachate movement would not be impeded.
Navajo		Inadequate data for geotechnical evaluation.	
Arapahoe - Public Service Company of Colorado/Denver County, Denver, CO (FGD also)	B	10-12" avg. annual precip. (gross), -35" net; less than 1" annual runoff; avg. annual temp. = 45°F, range -25° to 90°. Tertiary formations, most probably lake and stream deposits; possibility of sedimentary cretaceous bedrocks; thin stony surficial deposits. SOUTHERN PLAINS REGION, extreme northwest corner, 20 mi. from ROCKY MOUNTAIN REGION.	High net evaporation may constrain severely local groundwater recharge, and flow at site may be deep regional flow. Thin surficial soils over sedimentary bedrock units may provide only a limited medium for monitoring and evaluation. Frost penetration is not a determinant in rating this site.
Cherokee - Public Service Company of Colorado/Adams County, Denver, CO	B	10-12" avg. annual precip. (gross), -35" net; less than 1" annual runoff; avg. annual temp. = 45°F, range -25° to 90°. Tertiary formations, most probably lake and stream deposits; possibility of sedimentary cretaceous bedrocks; thin stony surficial deposits. SOUTHERN PLAINS REGION, extreme northwest corner, 20 mi. from ROCKY MOUNTAIN REGION.	Net evaporation and frost action may limit infiltration and local groundwater flow. New pond may have produced only very limited leachate movement, very difficult to detect and evaluate. Thin soils over bedrock may limit monitoring activities because of constraints on flow.

Table 3.9.4 (cont.)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Martin Drake - Colorado Springs Department of Public Utilities/ El Paso County, CO (Ash processed on a wet basis and trucked to landfill; landfill 20 mi. from plant, 2 yrs old, 8' deep, contains 20% BA, 80% FA; 6 monitoring wells at landfill site)	B-	16" avg. annual precip. (gross), 0" net; avg. annual temp. = 45°F, range -25° to 90°; frost penetration = 45". Bedrock consists of Cretaceous sandstones and shales, no soil data available but soils probably thin and rocky.	Rating developed after site visit.
Hayden Station - Colorado-UTE Elec. Assn., Inc./Routt County, CO (15-20 mi. west of Steamboat Springs, CO)		16" avg. annual precip. (gross); avg. annual temp. = 35-40°F, range -30° to 80°. Thin stony soil, mountainous terrain. Extremely complex geology, only 25 mi. west of Continental Divide; ROCKY MOUNTAIN REGION (Wyoming Basin).	Inadequate data for geotechnical evaluation.
Four Corners - Arizona Public Service/Farmington, NM (on Chaco River)	B	10-12" avg. annual precip. (gross), -40" net; avg. annual temp. = 50°F, range -10° to 100°; frost penetration = 5 - 10". Sedimentary cretaceous bedrock, shales, SS; shaley desert soils; Colorado Plateau section of Region J, ROCKY MOUNTAIN REGION.	Net evaporation may limit local recharge so that groundwater flow is deep, perhaps confined to bedrock units. Frost action would not influence infiltration or leachate movement. Predominantly shaley bedrock, with some sandstone, beneath desert soils may simplify flow patterns but local anomalies may occur above sandstone.
San Juan		Inadequate data for geotechnical evaluation.	Landfilling is presently being done in an old coal mine; the mining operations may severely constrain the monitoring efforts. Drainage through the mine could physically and chemically affect groundwater flow. The underlying bedrock consists of coarse sandstone. Surface soils are thin and pervious. Regional groundwater flow at great depth should predominate. This combination of conditions may make monitoring very difficult.
Hunter - Utah Power & Light/ Emery County, UT, 39°09'30"N, 111°00'35" W (All wastes dewatered, then landfilled. FGD also.)	C	10" avg. annual precip. (gross), -30" net; avg. annual temp. = 50°F, range -15° to 100°; frost penetration = 20" per winter season. Landfill is 20' thick; 16' down to water table; 13% BA, 51% FA, 36% FGD in landfill; codisposal; silty clay soil liner; silty clay to 10.5' below fill, then Blue Gate Siltstone; upper Cretaceous bedrock.	Silty clay soil liner below landfill, over clay subsoil over siltstone constitute conditions for very slow contained flow of groundwater and leachate: difficult to sample and monitor. Arid climate limits water for infiltration and frost action impedes winter infiltration, to virtually eliminate local recharge.

Table 3.9.4 (cont.)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Huntington - Utah Power & Light/ Emery County, UT (near Price, UT)	C	10"+ avg. annual precip. (gross); avg. annual temp. = 45°F, range -20° to 80°; frost penetration = 15" max. Cretaceous to tertiary sedimentary rocks; sandy desert soils; shales, sandstones, some conglomerates. Plateau section of Region J, ROCKY MOUNTAIN REGION.	Sparse sandy desert soils over bedrock units of greatly varying permeability create a very complex and erratic flow system. Net precipitation and only shallow frost penetration should produce infiltration sufficient to support local groundwater flow.
Jim Bridger - Pacific Power & Light/Sweetwater County, Rock Springs, WY (FGD to be installed)	B-	8.5" avg. annual precip. (gross), -30" net; avg. annual temp. = 35° - 40°F, range -20° to 90°; frost penetration more than 20". Cretaceous sandstones, shales and conglomerates, tertiary SS, Sh and conglomerates; shaley, sandy desert surficial deposits. ROCKY MOUNTAIN REGION (Wyoming Basin).	Thin sandy soils over sandstone, shale and conglomerate bedrock units may furnish pervious but a really constrained flow media. High net evaporation and significant frost action (which impedes winter infiltration) constrain local groundwater recharge; flow at site may be deep, regional flow only.
Naughton		Inadequate data for geotechnical evaluation.	
Apache - Arizona Electric Power Coop, Inc./Cochise County, AZ (40 mi. southeast of Tucson, AZ, Region K)	B-	8" avg. annual precip. (gross), -40" net; avg. annual temp. = 65°, range 40° to 115°; frost penetration not a factor. Pond built on dry lake sediments 8-10' clay, over 2-5' of organic soil over sand and sediments to a depth of 1500'. Very little likelihood of obtaining data capable of interpretation for groundwater studies; bedrock unimportant; quaternary sediments.	Deep lake bed soils and sediments of highly varying permeability may create easily understood flow system but local anomalies may occur. Net evaporation in arid area severely constrains local recharge of groundwater.
Gardner - Nevada Power/ Clark County, NV (FGD-pond, Bottom ash LF, most FA sold; 21 monitoring wells 25' deep)	C	8" avg. annual precip. (gross), -52" net; avg. annual temp. = 60°F, range 0° to 115°; frost penetration N.A. Plant located in closed valley on valley fill of Quaternary silt, clay and sand; playa deposits. Area bordered by volcanic deposits and bedrock ridges. FGD wastes and fly ash/bottom ash deposits placed on 50' of clay; 5' to water table, below pond; 50' to water table below landfill.	Very high net evaporation seriously limits local groundwater recharge. Very low permeability soils create very slow groundwater/leachate flow. Underlying volcanic bedrock, at depths of 15 meters, has erratic variations in permeability. This site would be very difficult to monitor and evaluate.

Table 3.9.4 (cont.)

Note: Ratings described in Section 2.7

Plant/Location	Rating	Background	Comments
Mohave - Southern California Edison/Clark County, NV, 36°07'30" N, 114°35'00" W (Davis Dam, 80-90 miles from South Las Vegas)	B+	8" avg. annual precip. (gross), -25"+ net; avg. annual temp. = 65°F, range 10° to 110°; frost penetration not a factor. Hydrologic situation makes obtaining data on groundwater contamination very unlikely (dry landfill, high net negative precip.) Metamorphic and volcanic bedrocks, most of precambrian, mixed with tertiary volcanic rocks and quaternary sediments; 85' sand and gravel, over 15' of clay over 100' sand and gravel to water table. Region K, BASIN AND RANGE REGION.	Local coarse alluvium over clay layer may furnish a contained flow system amenable to monitoring and analysis. Local recharge of groundwater should be minimal in this arid, net-evaporation area. Groundwater may persist at depths of more than 60 meters in regional flow pattern. System may be difficult to evaluate.
Centralia - Pacific Power & Light/ Lewis County, WA (30 mi. north of Oregon border at Centralia, WA)	C -	42" avg. annual precip. (gross), est. 80"; very little evaporation; avg. annual temp. = 45°F, range 0°F to 80°. Cenozoic volcanic bedrock; perhaps some tertiary volcanics; deep residual clayey soil over volcanic rock. 3-9' sandy clay, 9-15' soft peat, organic clay, 50-65' silt/sandy clay; water table 0 - 4' below surface. PACIFIC COASTAL REGION (M).	Very high persistent precipitation and very shallow frost penetration should produce copious infiltration and abundant local groundwater flow. However, deep clayey residual soil should make flow rate very slow, difficult to monitor and sample. Underlying volcanic bedrock may be erratically variant in permeability and could render flow evaluation almost impossible.

3.9.4 Other Site Selection Considerations

3.9.4.1 Discussion

The other considerations for candidate site designation in the Great Plains and West regions were based on both the variety of environmental conditions and the various waste disposal practices that prevail in the regions. Of the regions under consideration, the far west is the most arid with the Great Plains somewhat less arid, and the West Coast receiving excessive precipitation. Net evaporation often exceeds precipitation in the driest areas by a factor of three or four. A large portion of the region is mountainous with varied and sometimes sparse surface sediments. These environmental factors combine to create locations where prospective study sites may exist under conditions that are unfavorable to the detection of migrating waterborne contaminants, especially in groundwater. These regions are also subject to more extremes of temperature than their eastern counterparts.

Southern Plains (Region H)

This region is typified by generally low amounts of yearly rainfall and fairly high evaporative rates, but it generally does not represent an area of climatic extremes. Conditions are such that rapid, large-scale leachate migration to groundwater would not be anticipated. In the region of some plants, the Second National Water Assessment (21) indicated that ground and/or surface water demands have reached a critical stage.

Northern Plains (Region I)

Compared with the Southern Plains, the climate of this region is more severe. There are generally greater temperature extremes, less rainfall, and fewer frost-free days. While sufficiency of (or lack of reliance on) either ground or surface water supply appears typical, exceptions are noted in Exhibit D where reported.

Rocky Mountain (Region J)

The Rocky Mountain Region represents one that largely exemplifies the types of environmental extremes that can occur in western regions. In the areas of plant locations, groundwater and/or surface water demands can be a critical issue. Precipitation levels are exceedingly low throughout the region, and temperature extremes with a short frost-free period are typical conditions.

Great Basin (Region K)

This area is characterized by extremely low precipitation, moderating temperatures (not extremes), and a longer frost-free period (between 150 and 240 days) than in any of the other western locations discussed above.

This area is characterized by extremely low precipitation, moderating temperatures (not extremes), and a longer frost-fee period (between 150 and 240 days) than in any of the other western locations discussed above.

Columbia Plateau (Region L)

Region L contains no plants considered in this study.

Pacific Coastal (Region M)

Only one facility was considered from this region, Centralia, of Pacific Power & Light. The climatic/environmental conditions in the area around this facility are in direct contrast to those at other facilities being reviewed from the western area. Rainfall is very high and water supply is not a critical issue. Temperature extremes are moderated in this coastal area, and the frost-free period is about 150 days.

3.9.4.2 Ratings

Table 3.9.5 presents the ratings for other site selection factors for the disposal operations in the western regions. Rating methodology is discussed in Section 2.8 and individual plant information is presented in Exhibit D.

3.9.5 Candidate and Back-Up Sites

The targeted number of candidate sites in this region was four with up to three back-up sites. This region is particularly important in terms of future growth. Landfilling and interim ponding/landfilling are dominant modes of disposal in the western environmental setting.

The recommended candidate and back-up sites were:

Waste Type/ Disposal Method	Candidate Sites	Back-up Sites
Coal Ash Only		
Combined Fly and Bottom Ash/ Interim Pond; Landfill	Arapahoe	---
Combined Fly and Bottom Ash/ Landfill (CS)	Drake	Jim Bridger
Fly Ash/Landfill (UL); Combined Fly and Bottom Ash/Interim Pond (CS); Landfill (UL); Bottom Ash/Interim Pond (UL); Landfill (UL)	Dave Johnston	---
Fly Ash/Landfill; Bottom Ash/ Interim Pond; Landfill	---	Comanche
Coal Ash and FGD Waste		
Fly/FGD Waste/Interim Pond (CS); Pond (UL); Bottom Ash/Interim Pond (CS); Pond (UL)	Colstrip	---

Table 3.9.5

OTHER SITE SELECTION RATINGS FOR DISPOSAL OPERATIONS IN THE GREAT PLAINS AND WEST REGIONS OF THE U.S. (REGIONS H - M)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. ≥7000 Degree Days F (+)	Ppt. ≤16"(40cm)or ≥48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
REGION H Comanche, Pub.Ser.of Colo.	BA Int. Pond 3^+	0	+	0	0	+	+	NA	NA	0	0	0	NA	0	NA
	FA Fill 7^+	0	+	0	0	+	+	NA	+	+	0	0	+	+	0
	BA Fill 5^+	0	+	0	0	+	+	NA	+	+	0	0	+	0	-
Jeffrey, Kansas P&L	BA FGD Pond 5^+	0	0	0	0	+	+	NA	NA	0	+	0	NA	++	NA
LaCygne, Kansas City P&L	FA/FGD Pond 1^+	0	0	0	0	0	0	NA	NA	0	0	0	NA	+	NA
	BA Pond 1^+	0	0	0	0	0	0	NA	NA	0	0	0	NA	+	NA
Lawrence, Kansas P&L	FGD/NA 2^+	0	0	0	0	0	+	NA	NA	NA	NA	NA	NA	+	NA
Asbury, Empire Dist. Elec	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Hawthorn, Kansas City P&L	FA/FGD Pond 1+	0	0	0	0	NA	NA	NA	NA	0	0	0	NA	+	NA
Montrose, Kansas City P&L	NA *	0	0	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Harrington, Southwestern Pub. Serv.	NA 2^+	0	0	0	0	+,	+	NA	NA	NA	NA	NA	NA	NA	NA

Reproduced from best available copy.

Table 3.9.5 (Continued)

Plant & Utility	Total Rating (+ and -)	REGIONAL/GENERIC FACTORS: Climate: Temp. ≥7000 Degree Days F (+)	Climate: ppt. ≤16"(40cm)or ≥48"(120cm) (+)	Climate: ≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	Water Use: G.W. (+)	Water Use: S.W. (+)	SITE-SPECIFIC FACTORS: Setting: Age and Substrate (+ or -)	Setting: Proximity to S.W. (+)	Mitigative Controls: Dewatered/ Dry Disposal (+)	Mitigative Controls: Placed Liners (+)	Mitigative Controls: Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
REGION I Colstrip, Montana Power	BA Pond 7^+	+	+	+	0	0	0	NA	NA	0	NA	0	+	+++	NA
	FA/FGD Int.Pond 7^+	+	+	+	0	0	0	NA	NA	0	NA	0	+	+++	NA
	BA/FA FGD Pond 6^+	+	+	+	0	0	0	NA	NA	0	NA	0	+	+++	-
North Omaha Stat. Omaha Pub. Power	FA/BA Landfills 3+	+	0	0	0	NA	+	NA	NA	+	0	0	NA	NA	NA
Sheldon Station, Nebraska Pub.Pow.	FA/BA Landfills 4^+	+	0	0	0	+	+	-	NA	+	0	0	+	NA	NA
Coal Creek, Cooperative Power Assoc.	NA 3^+	+	+	+	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Leland Olds Basin Elec. Pow. Coop.	FA/BA Ponds 4+	+	+	+	0	0	0	NA	NA	0	0	0	+	NA	NA
Milton Young Stat. Minnkota Power Coop.	BA/FA FGD Fill 5^+	+	0	+	0	0	0	-	NA	+	0	0	++	++	-
Dave Johnston, Pacific P&L	BA Pond 8^+	+	+	+	0	0	+	NA	NA	0	+	0	+	++	NA
	BA/FA Pond 8^+	+	+	+	0	0	+	NA	NA	0	+	0	+	++	NA
	BA/FA Fills 8^+	+	+	+	0	0	+	+	NA	+	0	0	++	+	-

Table 3.9.5 (Continued)

		REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate				Water Use		Setting		Mitigative Controls					
Plant & Utility	Total Rating (+ and -)	Temp. >7000 Degree Days F (+)	ppt. <16"(40cm)or >48"(120cm) (+)	≤ 150 Frost-Free Days (+)	Contaminant Migration Factor (Climate and Soils) (+)	G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)	Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
REGION J Cholla, Arizona Pub.Ser.	FA/FGD Ponds 3+	0	+	+	0	0	0	NA	NA	0	0	0	NA	+	NA
Navajo, Salt River Proj.	NA 1+	0	+	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
Arapahoe, Pub. Ser. of Colorado	BA/FA Int. Ponds 7+	+	+	+	0	+	+	NA	NA	NA	NA	0	+	+	NA
	BA/FA Fills 4+	+	+	+	0	+	+	NA	NA	NA	NA	0	NA	NA	-
Cherokee Pub. Ser. of Colorado	BA/Pond 5+	0	+	+	0	+	+	NA	NA	NA	NA	NA	+	NA	NA
	BA/FA Landfill 5+	0	+	+	0	+	+	-	NA	+	+	0	+	NA	-
Drake, Colorado Spring Dept. of Public Utilities	BA/FA Fill 7+	0	+	+	0	+	+	-	NA	+	+	0	++	NA	NA
Hayden Station Colorado Utilities Elec. Assoc.	BA/FA Fill 6+	+	+	+	0	0	0	NA	+	+	0	0	+	NA	NA
Four Corners Arizona Pub.Ser.	Int. Pond/ Fill 2+	0	+	+	0	NA	NA	NA	NA	+	NA	0	+	NA	=
San Juan Pub.Ser. of New Mexico	BA/FA Fill 5+	0	+	+	0	NA	NA	NA	NA	+	NA	0	+	+	NA
Hunter, Utah P&L	BA/FA/ FGD Fill 3+	0	+	+	0	0	0	-	NA	+	0	0	NA	+	NA
Huntington, Utah P&L	BA/FA/ FGD Fill 4+	0	+	+	0	0	0	NA	NA	+	0	0	NA	+	NA

Table 3.9.5 (Continued)

Plant & Utility	Total Rating (+ and -)	REGIONAL/GENERIC FACTORS						SITE-SPECIFIC FACTORS							
		Climate			Contaminant Migration Factor (Climate and Soils) (+)	Water Use		Setting		Mitigative Controls			Baseline Environmental Studies (+ or ++)	Other Study Opportunities (e.g., Recycle, Land Use, Biota, FGD) - No Limit (+)	Complicating Factors (- or =)
		Temp. ≥7000 Degree Days F (+)	ppt. ≤16"(40cm) or ≥48"(120cm) (+)	≤150 Frost-Free Days (+)		G.W. (+)	S.W. (+)	Age and Substrate (+ or -)	Proximity to S.W. (+)	Dewatered/ Dry Disposal (+)	Placed Liners (+)	Chemical Pretreatment (+)			
REGION J (Cont.) Jim Bridger, Pacific P&L	BA/FA Fill 6+	+	+	+	0	0	0	NA	NA	+	0	0	++	+	-
Naughton, Utah P&L	NA 3+	+	+	+	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA
REGION K Apache, Arizona Elec. Power Coop.	BA/FA FGD Pond 3+	0	+	0	0	0	+	-	NA	0	0	0	NA	++	NA
Gardner, Nevada Power	FGD Pond 3+	0	+	0	0	+	+	-	NA	0	0	0	NA	+	0
	BA/FA Fill 4+	0	+	0	0	+	+	-	NA	+	0	0	+	NA	0
Mohave, So. California Edison	FA/BA Landfill 3+	0	+	0	0	+	+	+	NA	NA	0	NA	+	NA	=
REGION M Centralia, Pacific P&L	Int. BA/FA Ponds 4+	0	+	+	NA	0	0	+	NA	0	+	0	NA	+	-
	BA/FA Landfill 5+	0	+	+	NA	0	0	NA	NA	+	+	0	+	+	-

Note: Rating methodology is described in Sec. 2.8; information on plants is summarized in Exhibit D.

Reproduced from best available copy.

Some important points to note are:

- The Young plant already had an on-going EPA/DOE monitoring program and, hence, was not considered. Results from the on-going program in the plant are available and can be incorporated into the assessment effort for this project.
- Some plants (like Jeffrey) were rejected due to the fact that there were less than two years of stable operation at the disposal site.

Table 3.9.6 provides an overview of the candidate and back-up sites' characteristics. A brief description of these sites follows:

Arapahoe Plant, Public Service of Colorado

Arapahoe of Public Service of Colorado is a small plant and was recommended as a candidate site since the disposal mode (combined fly and bottom ash to interim pond/landfill) was typical and the environmental setting was very favorable. Cost data was considered potentially important for this mode of disposal (interim pond/landfill) in small plants.

Drake Plant, Colorado Springs Department of Public Utilities

Drake of Colorado Springs Department of Public Utilities was designated a candidate site since it practiced a typical disposal mode (combined fly and bottom ash to landfill) in this region under favorable settings and could provide cost data for projection to small plants. The plant practiced mitigative control and offered favorable hydrogeologic and environmental settings.

Colstrip Plant, Montana Power

Colstrip of Montana Power was designated as a candidate site for the following reasons: (1) the lime/alkaline ash FGD scrubbing system, although not necessarily typical, may represent a good example of conditions favorable to isolation of contaminants of interest to this program; (2) site hydrogeology appeared favorable; and (3) several monitoring wells already exist around the various disposal ponds, potentially affording useful background data.

Johnston Plant, Pacific Power & Light

Dave Johnston of Pacific Power & Light was designated as a candidate site since its disposal practice (combined fly and bottom ash to interim pond/landfill) is typical and site characteristics appeared to be favorable. Good water balance data were available. This site offers favorable geologic and environmental conditions, including apparent presence of alluvium sands underlying fill, and good baseline data.

Table 3.9.6

RECOMMENDED CANDIDATE AND BACK-UP SITES - GREAT PLANS AND THE WEST - REGIONS H, I, J, K, L, AND M

	Candidate	Description	Assessment of Disposal Operations	Geotechnical/Hydrogeologic Considerations	Other Factors
1	Arapahoe Public Service of Colorado Denver, CO	250-Mw plant started up in 1950. Combined fly and bottom ash to an interim pond and then to a landfill.	Small plant important for cost data. Typical disposal mode. 1 1/2+	High net evaporation may constrain groundwater recharge. Thin surficial soil over sedimentary bedrock. B	Favorable combination of disposal mode and environmental setting. 7+ pond 4+ landfills
2	Drake Colorado Springs Department of Public Utilities El Paso County, CO	282-Mw plant started in 1962. Combined fly and bottom ash disposal in a lined landfill.	Small plant important for cost data. Typical disposal mode. 3 1/2+	Thin and rocky soils over sandstone and shale bedrock make for complex regime. Frost action impedes winter infiltration. B-	Important environmental setting to study impacts. 7+
3	Colstrip Montana Power Rosebud County, MT	720-Mw plant started up in 1975. FGD started in 1975. Fly ash/FGD disposal in a lined interim pond and then to an unlined final pond. Bottom ash disposal to a unlined interim pond and then to an unlined final pond,	Disposal mode atypical, but bracket analogous practice. 4+	Stony soil deposits over interbedded sandstone make for complex flow. Mine environment may simplify flow regime. B+	Favorable combination of scrubber and environment; existing wells. 7+ interim ponds 6+ final pond
4	Dave Johnston Pacific Power and Light Converse County, WY	750-Mw plant started up in 1959. Combined fly and bottom ash disposal to a unlined interim pond and then to an unlined landfill. Fly ash to an unlined landfill. Bottom ash to an unlined interim pond and then to an unlined landfill.	Important disposal mode in region. 3 1/2+	Thin strong soil over sedimentary bedrock constrains monitoring local alluvium provides favorable medium for monitoring. Frost action impedes winter infiltration. B+	Climatic and water supply extremes; good baseline data. 8+
	BACK-UP SITES				
5	Comanche Public Service of Colorado Pueblo County, CO	778-Mw plant started up in 1973. Fly ash to a landfilled. Bottom ash disposal to an interim pond and then to a landfill.	Important disposal modes in region. 3+	Alluvium over sandstone and shale rock. Net evaporation, seasonal precipitation and shallow frost penetration make for limited infiltration. B+	Important disposal mode and setting of extreme conditions. 7+ fly ash fill 5+ bottom ash fill 3+ bottom ash pond
6	Jim Bridger Pacific Power and Light Sweetwater, NY	1525-Mw plant started up in 1974. FGD just started up. Combined fly and bottom ash to a landfill which is a mine.	Large plant and typical disposal mode. 3+	Thin sandy soil over bedrock units provided pervious but constrained flow. Frost action and net evaporation constrain groundwater recharge. B-	Important combination of environmental setting and disposal mode, baseline data. 6+

Comanche Plant, Public Service of Colorado

Comanche of Public Service of Colorado was designated as a back-up site since it practiced typical disposal operations (fly ash to landfill and bottom ash to interim pond/landfill). Favorable hydrogeology and some water balance data availability were positive factors. Its dry fly ash fill was located in an area expected to overlie a relatively pervious alluvium of the Arkansas River. Comanche had the potential of being a back-up for Dave Johnston with respect to the landfilling of fly ash.

Jim Bridger, Pacific Power & Light

Jim Bridger of Pacific Power & Light practiced a typical disposal mode (combined fly and bottom ash to a landfill) in this region and was designated a back-up site for the Drake plant. Environmental and hydrogeologic settings appeared conditionally favorable.

Some other sites considered potentially interesting in this region (no in any special order) were:

- Hayden Station, Colorado Utilities Electric Association
- Four Corners, Arizona Public Service

4.0 CANDIDATE AND BACKUP SITES - FINAL SELECTION

As was emphasized in Sections 2.0 and 3.0, the selection of candidate and back-up sites was the result of an iterative process.

- First, the plants in each region were screened to develop a list of plants that might be suitable for consideration as candidate and back-up sites. In such selections, the investigators attempted to keep to the targeted number in each region but were not absolutely limited to that number. The overriding goal was to choose good plants in the various regions.

- Second, the list of plants for all the regions that resulted from this filtration process contained about 26 plants. These were then ranked during iterative group discussions leading to the recommendation of about 18 as candidate sites. The remainder became back-up sites.

The final categorization and the ranking leading to the site recommendations took into account three categories of variables. Each is discussed below.

4.1 WASTE TYPE

The available information indicated that six categories of wastes constitute the vast majority of wastes sent to disposal: fly ash, bottom ash, combined fly and bottom ash, FGD waste alone, FGD waste and fly ash, and stabilized FGD waste. These combinations are likely to remain the major options of importance in the future.

4.2 TYPE OF DISPOSAL

Ponding and landfill operations are practicable for many wastes. However, stabilized FGD waste disposal in landfills is likely to be a major option in the future. Dravo's Calcilox® process can achieve stabilization in a slurry destined for a pond; and there are two plants (Bruce Mansfield and Pleasants) that practice this kind of disposal. This disposal practice, however, is dependent on the availability of the proprietary additive Calcilox®; hence, this method was considered atypical. Stabilized FGD waste disposal by landfilling alone was emphasized.

Similarly, FGD wastes, when disposed alone, are usually disposed of by ponding only. In the future, with forced oxidation methods, FGD waste disposal by itself in the form of gypsum stacks may be practical; however, such disposal practices do not exist for a full-scale plant at present. Hence, FGD waste disposal by ponding alone was also emphasized.

When bottom ash is disposed of alone, ponding appears to be the usual method. Hence, bottom ash disposal by itself in landfills was not emphasized. It should be noted, however, that combined fly and bottom ash disposal, both in ponds and landfills, was emphasized in recognition of its prevalence.

4.3 CLIMATIC AND GEOLOGIC CONDITIONS

In evaluating the final ranking of sites, it was more appropriate to divide the country into three large environmental zones--Coastal, Interior, and Western. This division was for purposes of convenience and use in achieving assessment coverage of ranges of high-priority types of impacts (impacts on groundwater, non-point impacts on surface waters, and mitigative design, control, or management practices under different environmental conditions). The Coastal zones were those that were within a few miles of the Atlantic, Gulf, or West coasts. In Section 3.0 the plants in Regions H, I, J, K, L, and M were considered Western plants. However, the majority of Regions H and I are more nearly described as part of the Interior zone. Montana, Wyoming, Colorado, New Mexico, or further west were classified as part of the Western zone. The rest of the country was grouped into the Interior zone.

4.4 FINAL RANKING

Ranking of the candidate and back-up sites using the above categories in each region as described above is shown in Table 4.1; the table presents the overall data on all the 26 sites (the recommended candidate and back-up sites) together with pertinent information on the type of disposal and the ratings.

To describe the ranking process, Table 4.2 is presented showing the 26 plants in terms of waste type, mode of disposal, and environmental zones. To describe the process of developing the final breakdown into candidate and back-up sites, the following illustrative examples are offered.

- Fly Ash Ponding. This is primarily practiced in the Interior zone. Three plants were considered potentially suitable--Columbia I (Discussion Region F), Clifty Creek (Discussion Region D), and Sporn (Discussion Region B). Columbia I and Clifty Creek were considered potentially more suitable and were recommended as candidates. Sporn was a back-up site for fly ash-ponding. Sporn in West Virginia, Clifty Creek in Indiana, and Columbia I in Southern Wisconsin are not exactly identical; however, there is sufficient commonality in a broad range of site conditions that one of them could provide needed data if the site conditions are suitable. Columbia I and Clifty Creek are preferred candidate sites for further evaluation.

Table 4.1

RECOMMENDED CANDIDATE AND BACK-UP SITES - ALL REGIONS

Region	CANDIDATE SITES						BACK-UP SITES					
	Plant Utility Size	Type of Disposal	Rating			Comments	Plant Utility Size	Type of Disposal	Rating			Comments
			Disp. Oper.	Hydro-Geo.	Other				Disp. Oper.	Hydro-Geo.	Other	
A1	Smith Gulf Power Bay County, FLA (340 Mw)	Combined fly and bottom ash to an unlined pond.	1 1/2+	B+	3+	Typical disposal practice, coastal region, sandy site high water table; almost no misc. influent.	Big Brown Texas Power and Light Freestone County, TX (1186 Mw)	Fly ash to a clay lined landfill. Bottom ash to a clay lined pond.	3 1/2+	B	4+ lndfl/ BA pond	Landfill disposal has future potential in region. Surface water utilization critical in region. Net evaporation may limit groundwater flow.
	Tombigbee Alabama Electric Coop Washington County, AL (585 Mw)	FGD wastes to a lined pond.	3 1/2+	A-	5+	Important disposal mode coastal region & control practice to bracket impacts. Alluvial soils						
A2	Allen Duke Power Gaston County, NC (1155 Mw)	Combined fly and bottom ash to an unlined pond.	2 1/2+	A-	3+	Typical disposal practice & typical setting in region. Outstanding baseline data. Deep silty residual soils.	Sutton Carolina Power and Light New Hanover, NC (671 Mw)	Combined fly & bottom ash to an unlined pond.	2 1/2+	A-	4+	Typical disposal practice coastal location. Sandy soil over sedimentary rocks. High precipitation.
	Winyah S. Carolina (Public Serv. Authority Georgetown County, SC (630 Mw)	FGD wastes to an unlined pond. Combined fly and bottom ash probably ponded.	3 1/2+	A-	4+	FGD ponding in coastal location may define impact boundary; thick pervious coastal sediments high precipitation.						
B B	Elrama Duquesne Light and IUCS Washington County, PA (510 Mw)	FGD wastes stabilized by CSi then to an offsite landfill. Combined fly and bottom ash to an unlined interim pond then to the same landfill.	4+	B+	6+ (fill) 3+ (pond)	Stabilized FGD waste important. Alluvium provides good media for monitoring. Important setting.	Sporn Central Operating Mason County, WV (1105 Mw)	Fly ash to an unlined pond. Bottom ash to an unlined interim pond and then sold.	2 1/2+	B	1+ (FApond) 1+ (FAfill) 3+ (BApond)	Ponding mode important. Fine sandy soil provides good media for monitoring; climate permits only limited local recharge of groundwater.
Keystone	Keystone Pennsylvania Elec. Armstrong County, PA (1872 Mw)	Fly ash to an unlined landfill. Bottom ash to an unlined interim pond then to the same landfill.	3+	B-	4+ (fill) 3+ (pond)	Important disposal mode in region. Silty clay over sandstone leads to complex flows.						

Table 4.1 (Continued)

RECOMMENDED CANDIDATE AND BACK-UP SITES - ALL REGIONS

Region	CANDIDATE SITE						BACK-UP SITE					
	Plant Utility Size	Type of Disposal	Rating Disp. Oper.	Rating Hydro-Geo.	Rating Other	Comments	Plant Utility Size	Type of Disposal	Rating Disp. Oper.	Rating Hydro-Geo.	Rating Other	Comments
B	Widows Creek TVA Jackson County AL (1977 Mw)	FGD wastes to an unlined pond. Combined fly and bottom ash to an unlined pond.	3 1/2+	C	5+	Important disposal modes. Geologic regime could be complicated. Environmental setting is important.						
C	NO SITES						NO SITES					
D	Powerton Commonwealth Edison Tazewell County, IL (1785 Mw)	Fly ash to an artificially lined landfill that is off-site. Bottom ash to the same landfill.	2 1/2+	B-	6+	Important disposal mode and setting in a large plant. Climate limits groundwater recharge.	Duck Creek Central Illinois Light Fulton County, IL (441 Mw)	Fly ash/FGD wastes to an unlined pond. Bottom ash to an unlined pond.	3+	B-	2+ Fly/FGD 1+ BA	Mode of disposal and setting important in region. Silty subsoil may result in complicated flow regime.
	Clifty Creek Indiana-Kentucky Electric Jefferson County, IN (1303 Mw)	Fly ash to a clay lined pond. Bottom ash to 2 clay lined ponds.	2+	B-	3+FA 2+BA 1+BA	Large plant with important disposal mode and setting. Low net precipitation limits groundwater recharge.	George Neal Iowa Public Ser. Woodbury County, IA (961 Mw)	Combined fly and bottom ash to an unlined pond.	2 1/2+	B	3+	Disposal mode is important in region; climatic extremes
E	Southwest Springfield City Utilities Greene County, MO (194 Mw)	Fly ash/FGD wastes to an artificially lined landfill. Bottom ash to an artifically lined interim pond and then to the same landfill.	3 1/2+	C (tentative)	2+ (fill) & (pond)	Small plant practice important for economic and engineering assessment. Acceptable environmental rating.						
F	Columbia I Wisconsin Power & Light Portage County WI (556 Mw)	Fly ash to an unlined pond. Bottom ash to an unlined pond	2+	A	6+	Important disposal mode for climate and setting, soils provide good medium per monitoring.	Huntley Niagara Mohawk Power Erie County, NY (828 Mw)	Fly ash to an unlined landfill. Bottom ash to lined and unlined interim pond and then to the same landfill.	3+	C	5+ (BA pond) 4+ (BA/FA fill)	Typical disposal mode in region of climatic extremes. Lined and unlined ponds available.

Table 4.1 (Continued

RECOMMENDED CANDIDATE AND BACK-UP SITES - ALL REGIONS

Region	CANDIDATE SITE						BACK-UP SITE					
	Plant Utility Size	Type of Disposal	Rating			Comments	Plant Utility Size	Type of Disposal	Rating			Comments
			Disp. Oper.	Hydro-Geo.	Other				Disp. Oper.	Hydro-Geo.	Other	
F	Presque Isle Upper Pennisula Generating Marquette County MI (301 Mw)	Fly ash to an unlined landfill. Bottom ash to unlined interim pond then to the same landfill.	3+	C	3+	Landfill important in region. Climate limits groundwater recharge.						
G	Sherburne County Northern States Power Sherburne County, MNMN (1440 Mw)	Fly ash/FGD wastes to a clay lined pond. Bottom ash to an interim pond and then sold.	3 1/2+	A-	8+ (FA/ FGD Pond) 2+ (BA pond)	FA/FGD pond in region of climatic extremes, employs mitigative controls, favorable geohydro rating.						
	A. S. King Northern States Power Washington County, MN (598 Mw)	Combined fly and bottom ash to an unlined landfill.	2+	C	5+	Typical disposal mode in region of climatic extremes.						
West	Arapahoe Public Service of Colorado Denver County, CO (250 Mw)	Combined fly and bottom ash to an interim pond then to a landfill.	1 1/2+	B	Ponds 7+ Land fill 4+	Small plant important for cost data; important environmental setting and disposal mode; high net evaporation constrains groundwater recharge.	Comanche Public Service of Colorado Pueblo County, CO (778 Mw)	Fly ash to a landfill. Bottom ash to an interim pond and then to the same landfill.	3+	B+	FA Fill 7+ BA Fill 5+ BA Pond 3+	Typical disposal in favorable environmental setting. Alluvial soil over sandstone. Climate constrain infiltration.
	Drake Colorado Springs Dept of Public Utilities El Paso County, CO (282 Mw)	Combined fly and bottom ash to a clay lined landfill.	3 1/2+	B⁻	7+	Small plant important for cost data; favorable environmental setting for disposal mode.	Jim Bridger Pacific Power and Light Sweetwater County, WY (1525 Mw)	Combined fly and bottom ash to a landfill which is a mine.	3+	B-	6+	Large 1525 Mw plant. Favorable environmental setting and disposal mode. sandy soil over bedrock provides pervious but constrained flow.

Table 4.1 (Continued

RECOMMENDED CANDIDATE AND BACK-UP SITES - ALL REGIONS

Region	CANDIDATE SITE						BACK-UP SITE					
	Plant Utility Size	Type of Disposal	Rating			Comments	Plant Utility Size	Type of Disposal	Rating			Comments
			Disp. Oper.	Hydro-Geo.	Other				Disp. Oper.	Hydro-Geo.	Other	
	Colstrip Montana Power Rosebud County, MT (720 Mw)	Fly ash/FGD wastes to a clay lined interim pond then to an unlined final pond. Bottom ash to a clay-lined interim pond then to the same final pond.	4+	B+	Int. Pond 7+ Final Pond 6+	Favorable environmental setting. Stony soil may cause complex flow.						
	Dave Johnston Pacific Power and Light Converse County, WY (750 Mw)	Fly ash to unlined landfill. Combined fly and bottom ash to a clay lined interim pond then to the same landfill. Bottom ash to unlined interim pond, then to the same landfill.	3 1/2+	B+	8+	Excellent combination of disposal mode and environmental setting. Frost action impedes infiltration.						

Table 4.2

FINAL TWENTY-SIX SITES

	Coast	Interior	West
1. **Fly Ash:**			
Pond	NA	Clifty Creek Columbia (I) Sporn	AT
Landfill	AT	Big Brown Huntley Powerton (AL) Presque Isle	Comanche D. Johnston
2. **Fly/Bottom Ash:**			
Pond	Elrama (I) Smith Sutton	Allen G. Neal Widows Creek	Arapahoe (I) D. Johnston
Landfill	AT	A. S. King Keystone	J. Bridger (M) Drake
3. **Fly Ash/FGD Waste:**			
Pond	NA	Duck Creek Sherburne County	Colstrip
Landfill	AT	Southwest (AL)	AT
4. **Stabilized FGD Waste:**			
Landfill	NA	Elrama	NA
5. **FGD Waste:**			
Pond	Tombigbee (L) Winyah	Widows Creek	AT

Table 4.2
(Cont'd)

6. Bottom Ash:

Pond	AT	Big Brown Clifty Creek Columbia (I) Duck Creek Keystone (I) Huntley (I) (AL) Presque Isle (I) Sherburne County Southwest (I) (AL) Sporn	Colstrip (DP) Comanche (I) D. Johnston (I)
Landfill	AT	Powerton (AL)	AT

(AL) = Artificially Lined

(AT) = Atypical Disposal Practice for Region

(DP) = Two Ponds in Series

(I) = Interim Pond/Landfill (interim/final)

(L) = Lined (exact liner unknown)

(M) = Mine

(NA) = None available at Present.

- Fly Ash Landfilling. Four plants were listed in the Interior zone (Powerton, Presque Isle, Big Brown, and Huntley) and two in the Western zone (Dave Johnston and Comanche). Among the Western plants, Dave Johnston was rated potentially more suitable for a candidate site. Presque Isle and Huntley were in regions of unusual but analogous conditions. Presque Isle was rated more suitable and a candidate site while Huntley became a back-up site. Powerton in Illinois and Big Brown in Texas offer examples of different settings and site conditions. Powerton appeared to denote representative Interior zone conditions to investigate the effectiveness of an artificial liner for an ash landfill. Big Brown was in an area of critical water use, a condition also existing in some Western zone plants. Hence, it was nominated as a back-up site if other sites with critical water use conditions are unsuitable.

- Stabilized FGD Wastes. Not many sites in the country are available where this practice has been operating for at least two years, and where good ratings for all the major selection factors are represented. The only such site was Elrama in the Interior zone and it was nominated as a candidate site.

- FGD Ponding. This is not a typical disposal practice but offers an important potential bracket on environmental effects. Winyah (unlined) and Tombigbee (lined) were both rated highly and nominated as candidates in the Coastal zone. Widows Creek in the Interior zone also has other disposal operations and was retained as a candidate site. On balance, for this mode it is unlikely that more than one site will ultimately be studied.

The above examples illustrate the iterative process that resulted in the final list of sites. The process was necessarily one of considering trade-offs and involved judgemental decisions by the ADL Team. In addition to the 26 sites, the ADL Team selected other potentially suitable candidates in each region. These are identified in Section 3.0.

To place the selection process and recommendations in perspective, the following additional tables are presented.

- Table 4.3 provides a categorization of the recommended candidate and back-up sites by waste type/disposal mode and region. For many disposal modes there are no recommended sites in some regions; this is usually because such practice is not very common in that particular region. For example, fly ash ponding or landfill alone in the Coastal zone has no candidate sites because such practice is not employed there.

Table 4.3

RECOMMENDED CANDIDATE AND BACK-UP SITES

	Candidate			Backup		
	Coast	Inter	West	Coast	Inter	West
1 Fly Ash: Pond	NA	Columbia I Clifty Creek	AT	NA	- Sporn	AT
Landfill	AT	Powerton (AL) Presque Isle	D. Johnston	AT	Big Brown Huntley	Comanche
2 Fly/Bottom Ash: Pond	Smith	Elrama (I) Widows Creek Allen	Arapahoe (I) D. Johnston (I)	Sutton	G. Neal	-
Landfill	AT	Keystone A. S. King	Drake	AT	-	J. Bridger (M)
3 Fly/Ash/FGD Waste: Pond	NA	Sherburne County	Colstrip (DP)	NA	Duck Creek	-
Landfill	AT	Southwest (AL)	AT	AT	-	AT
4 Stabilized FGD Waste:	NA	Elrama	NA	NA	-	NA
Landfill	NA	Elrama	NA	NA	-	NA
5 FGD Waste: Pond	Winyah Tombigbee (L)	Widows Creek	AT	-	-	AT
6 Bottom Ash: Pond	AT	Sherburne County Columbia I Clifty Creek Presque Isle (I) Southwest (I) (AL) Keystone (I)	Colstrip (DP) D. Johnston (I)	AT	Big Brown Duck Creek Huntley (I)(AL) Sporn	Comanche (I)
Landfill	AT	Powerton (AL)	AT	AT	-	AT

(AL) = Artificially Lined

(I) = Interim Pond/Landfill (interim/final)

(DP) = Two ponds in series

(L) = Lined (exact liner unknown)

(AT) = Atypical disposal practice for region

(M) = Mine

(NA) = None available at present

Similarly, fly ash ponding by itself is an atypical operation in the West and hence, there are no candidate sites for that method in those regions. Combined fly and bottom ash landfilling in the Coastal region is not a current practice and hence, there are no candidate sites.

Similarly, it is important to mention that bottom ash ponding seems to have a number of candidate sites, particularly in the Interior Region. This is not the result of a strong effort to select bottom ash ponding; these sites were selected for one of the previous five categories of disposal; however, at these sites bottom ash ponding is also practiced so that the opportunity to study one or more bottom ash ponds may be created as a by-product of the original designation of these sites for other reasons.

- Table 4.4 presents an alphabetical list of the candidate and back-up sites.

- Table 4.5 presents the categorization of the nominated candidate and back-up sites by region, by size, by state, and by disposal mode.

  It is important to note that most of the candidate and back-up sites are in the Interior region . This is as would be expected since the majority of coal-fired power plants in the country are located in this region. However, in view of the potential growth of coal utilization in the West, the investigators have also selected a number of Western plants.

  The distribution by size again indicates that most of the plants are in the 200-to-1000-Mw range. A few larger plants have been selected together with two smaller ones (Southwest Station 194 Mw, Arapahoe 250 Mw) to facilitate engineering/economic projections to much smaller units.

  smaller

  The distribution of recommended plants by states indicates that 18 states are included in the selection of candidate and back-up sites, thus, covering a fairly broad region of the country. The distribution by disposal mode indicates a coverage of all major disposal options.

Table 4.4

LIST OF CANDIDATE AND BACK-UP SITES

1. Allen, Duke Power, NC
   1155 Mw
   Combined fly and bottom ash to an unlined pond.

2. Arapahoe, Public Service of Colorado, CO
   250 Mw
   Combined fly and bottom ash to an interim pond and then to a landfill.

3. Big Brown, Texas Power and Light, TX (Back-Up)
   1186 Mw
   Fly ash to clay substrate lined landfill.
   Bottom ash to a clay substrate lined pond.

4. Jim Bridger, Pacific Power and Light, WY (Back-Up)
   1525 Mw
   Combined fly and bottom ash to a landfill which is in a mine.

5. Cliftly Creek, Indiana-Kentucky Electric, IN
   1303 Mw
   Fly and bottom ash to separate clay substrate lined ponds.

6. Colstrip, Montana Power, MT
   720 Mw
   Fly ash and FGD waste to a clay substrate lined interim pond then to an unlined final pond.
   Bottom ash to a clay substrate lined interim pond and then to the same final pond.

7. Columbia I, Wisconsin Power and Light, WI
   556 Mw
   Fly and bottom ash to separate unlined ponds.

8. Comanche, Public Service of Colorado, CO (Back-Up)
   778 Mw
   Fly ash to a landfill.
   Bottom ash to an interim pond then to the same landfill.

9. Drake, Colorado Springs Department of Public Utilities, CO
   282 Mw
   Combined fly and bottom ash to a clay substrate lined landfill.

10. Duck Creek, Central Illinois Light, IL (Back-Up)
    441 Mw
    Fly ash, bottom ash and FGD waste to an unlined pond.

Table 4.4

LIST OF CANDIDATE AND BACK-UP SITES
(Continued)

11. Elrama, Duquesne Light and CSI, PA
510 Mw
FGD wastes stabilized by CSI process and disposed in an off-site 12 miles (18 km) away unlined landfill.
Combined fly and bottom ash to an unlined interim pond and then taken to the same landfill.

12. Huntley, Niagara Mohawk Power, NY (Back-Up)
828 Mw
Fly ash to an unlined landfill.
Bottom ash to lined and unlined interim ponds then to the same landfill.

13. Dave Johnston, Pacific Power and Light, WY
750 Mw
Fly ash to an unlined landfill.
Combined fly and bottom ash to a clay substrate lined interim pond then to the same landfill.
Bottom ash to an unlined interim pond then to the same landfill.

14. Keystone, Pennsylvania Electric, PA
1872 Mw
Fly ash to an unlined landfill.
Bottom ash to an unlined interim pond then to the same landfill.

15. A. S. King, Northern State Power, MN
598 Mw
Combined fly and bottom ash to an unlined landfill.

16. George Neal, Iowa Public Service, IA (Back-Up)
961 Mw
Combined fly and bottom ash to an unlined pond.

17. Powerton, Commonwealth Edison, IL
1785 Mw
Fly ash to an artificially lined landfill which is off-site.
Bottom ash to the same landfill.

18. Presque Isle, Upper Peninsula Generating, MI
301 Mw
Fly ash to an unlined landfill.
Bottom ash to an unlined interim pond then to the same landfill.

19. Sherburne County, Northern States Power, MN
1440 Mw
Fly ash and FGD wastes to a clay substrate lined pond.
Bottom ash to an interim pond and then sold.

Table 4.4

LIST OF CANDIDATE AND BACK-UP SITES
(Continued)

20. Smith, Gulf Power, FL
340 Mw
Combined fly and bottom ash to an unlined pond.

21. Southwest, Springfield City Utilities, MO
194 Mw
Fly ash and FGD wastes to an artificially lined landfill.
Bottom ash to an artificially lined interim pond then to the same landfill.

22. Sporn, Central Operating, WV (Back-Up)
1105 Mw
Fly ash to an unlined pond.
Bottom ash to an unlined interim pond and then sold.

23. Sutton, Carolina Power and Light, NC (Back-Up)
671 Mw
Combined fly and bottom ash to an unlined pond.

24. Tombigbee, Alabama Electric Coop, AL
585 Mw
FGD wastes to a lined pond.
Fly and bottom ash disposal method unknown.

25. Widows Creek, Tennessee Valley Authority, AL
1977 Mw
FGD waste to an unlined pond.
Combined fly and bottom ash to an unlined pond.

26. Winyah, South Carolina Public Service Authority, SC
630 Mw
FGD wastes to an unlined pond.
Combined fly and bottom ash probably ponded.

Table 4.5

CATEGORIZATION OF RECOMMENDED CANDIDATE AND BACK-UP SITES

	Candidate	Backup	Total
a. Distribution by Region			
Coastal	3	1	4
Interior	11	5	16
Western	4	2	6
Total	18	8	26
b. Distribution by Size			
MW			
<200	1	-	1
200-500	4	1	5
500-1000	7	4	11
>1000	6	3	9
Total	18	8	26
c. Distribution by State			
Alabama	2	-	2
Colorado	2	1	3
Florida	1	-	1
Illinois	1	1	2
Indiana	1	-	1
Iowa	-	1	1
Michigan	1	-	1
Minnesota	2	-	2
Missouri	1	-	1
Montana	1	-	1
New York	-	1	1
North Carolina	1	1	2
Pennsylvania	2	-	2
South Carolina	1	-	1
Texas	-	1	1
West Virginia	-	1	1
Wisconsin	1	-	1
Wyoming	1	1	2
Total	18	8	26

Table 4.5 (Continued)

CATEGORIZATION OF RECOMMENDED CANDIDATE AND BACK-UP SITES

d. Distribution by Disposal Mode

Note: Some sites have several disposal practices. Hence, numbers may not add up to total number of sites.

		Candidate	Backup	Total
• Fly Ash	Ponding	2	1	3
	Landfilling	3	3	6
• Combined Fly and Bottom Ash	Ponding	6	2	8
	Landfilling	3	1	4
• FGD Waste/ Fly Ash	Ponding	2	1	3
	Landfilling	1	-	1
• Stabilized FGD Wastes	Landfilling	1	-	1
• FGD Waste	Ponding	3	-	3
• Bottom Ash*	Ponding	8	5	13
• Bottom Ash	Landfilling	1	-	1

* Many of the sites selected for other reasons also practice bottom ash disposal alone.

On balance, the investigators conclude that the list of recommended sites provides a broad mix of options for further analysis leading to the selection of the final sites for the detailed monitoring. It should be noted, however, that additional evaluations at each of these 26 sites reveals information that, in some cases, altered the perception of their suitability. Detailed site visits together with an evaluation of the available environmental and hydrogeologic information formed the basis of the final Step 2 in the Site Selection Process and is described in Section 5.0.

REFERENCES

1. VERSAR, Inc., "Selection of Representative Coal Ash and Coal Ash/FGD Waste Disposal Sites for Future Testimony." Draft Report prepared for EPA-IERL, August 1979.

2. Jones, B.F., et al, "Study of Non-Hazardous Waste from Coal-Fired Electric Utilities." Report prepared by Radian Corp. for EPA-IERL, Res. Triangle Pk, N.C., December 15, 1978. Report # DCN 200-187-41-08.

3. Hunt, Charles B., "Physiography of the United States." New York: W.A. Freeman & Co., 1967.

4. Fenneman, N.M., "Physiography of Western United States." New York: McGraw-Hill Book Co., 1931.

5. Fenneman, N.M., "Physiography of Eastern United States." New York: McGraw-Hill Book Co., 1938.

6. Thornbury, W.D., "Principles of Geomorphology." New York: Wiley-Interscience, 1965.

7. Flue Gas Desulfurization Information System by PEDCo Environmental, Inc. for Environmental Protection Agency, Office of Research and Development, Washington, D.C.

8. Tuttle, J., et al, "EPA-Industrial Boiler FGD Survey-First Quarter 1979." Report prepared by PEDCo Environmental Agency, Office of Research and Development, Washington, D.C., April 1979. Report Number #PA-600/779 067b.

9. "New Source Performance Standards--Electric Utility Steam Generating Units." Federal Register 44(113):33580-33624, June 11, 1979.

10. Faber, J.W., "A U.S. Overview on Ash Protection and Utilization." Paper presented at the Fifth International Air Symposium, Atlanta, Georgia, Feb. 25-27, 1971.

11. Personal Communication, Hugh Miller of IU Conversion System, Hossham, PA to Chakra J. Santhanam of Arthur D. Little, Inc., April 1980.

12. "Health and Environmental Impacts of Increased Generation of Coal Ash and FGD Sludges," Report to the Committee on Health and Ecological Effects of Increased Coal Utilization, U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., 20460, December 1977.

13. Gilliam, L.R., ed., "Inventory of Power Plants in the United States, December 1979," U.S. Department of Energy [DOE/EIA-0095 (95)], Washington, D.C. 1981.

14. "Steam Electric Plant Factors (1981)," published by the National Coal Association, 1982.

15. "Annual Environmental Analysis Report." Report prepared by Mitre Corp., Consad Research, Control Data Corp., and Int. Research & Technology for ERDA, Sept., 1977. (Contract # EE-01-77-0135.)

16. "Waste and Water Management for Conventional Coal Combustion Assessment Report 1980," three volume report by Arthur D. Little, Inc. to U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. 20460; scheduled for NTIS publication, late 1982.

17. Sowers, G.B., et al, "Introductory Soil Mechanics and Foundations." New York: MacMillan Company, 1961.

18. "Inventory of Power Plants in the United States - April 1, 1979," U.S. Department of Energy, Washington, D.C., May 25, 1979. Report # DOE/EIA-0095.

19. Personal Communication, to B.A. Kuryk of Arthur D. Little, Inc. from S. Frank, Economic Regulatory Administrative Department of Energy, Washington, D.C., 20461, October 9, 1982.

20. "Steam Electric Plant Factors - 1978," National Coal Administration, Washington, D.C., 1979.

21. Second Annual Water Assessment, Council on Environmental Quality.

22. Sludge, August 21, 1979, p. 133.

23. Belcher, D.J., L.E. Gregg, D.C. Jenkins, K.B. Woods, "Origin and Distribution of U.S. Soils," Prelinear Technical Development Report 52, Civil Aeronautics Administration, Washington, D.C. 1946.

24. Flint, R.S., "Glacial Map of North America," Geological Society of America, New York, 1945.

25. Nation Weather Service.

26. "Steam Electric Plant Factors (1978)," published by the National Coal Association.

5.0 FINAL SELECTION

5.1 OVERVIEW

In this section some of the subsequent evaluations that led to the final selection of the six sites are briefly discussed. In presenting these factors it should be noted that the site selection process was a continuously iterative evaluation process with new technical information on sites becoming available throughout the process. Additionally, budgetary and time constraints in the project led to downward revisions on the actual number of sites. The combined effect of these led to the final selection of the six sites.

In June 1980, the Draft Site Selection Report was presented with a list of 18 candidate and 8 back-up sites for the evaluation. The data on this Site Selection Report was prepared with available information as of mid-1980. The subsequent approach towards site selection was to undertake individual visits focussing on the more attractive candidate sites where the utilities had expressed a particular desire to participate in this study. In addition, there were several mid-course evaluations that added to the total data base and the range of options available. The important considerations that acted synergistically are the following:

- Visits to the candidate and back-up sites were undertaken on a prioritized basis; that is, candidate sites were given higher preference for visit before back-ups. Additionally, as far as practical, several visits were combined into single trips. The visits did not take place in some cases because the utility concerned had indicated that they did not wish to participate in this study. In some other cases the candidate sites were quite suitable and hence, a visit to the back-up site was not undertaken.

- Tennessee Valley Authority in particular expressed a desire to have some of their plants evaluated. Hence, all of the coal-fired TVA power plants were evaluated.

- Mid-course evaluations were undertaken after the selection of the first few sites, taking into account engineering considerations on air pollution control systems and hence, the generation of these wastes. Sulfur rank, type of particulate control and the type of FGD control were evaluated as the site selection process went further into nominating some sites.

- Due to the strong desire on the part of the utility industry to have a site west of the Continental Divide, additional strong efforts were undertaken to select a site west of the Continental Divide. After considerable study, Apache plant of the Arizona Electric Cooperation was nominated as a seventh site. Ultimately, budgetary and time considerations led to this site not being developed.

- It was noted that a small plant has engineering costs associated with solid waste management that are different from those of the larger ones. Hence, some evaluations were also undertaken on considerably small plants. None of the small plants that were available appeared suitable on technical grounds.

The combined effect of all of these evaluations are summarized in the next subsections.

5.2 INDIVIDUAL MID-COURSE EVALUATIONS

5.2.1 TVA Assessment

A special effort was undertaken to study the Tennessee Valley Authority plants. In particular, data was gathered on the following TVA plants:

- Paradise
- Watts Bar
- Allen
- Bull Run
- Colbert
- Cumberland
- Gallatin
- John Sevier
- Johnsonville
- Kingston
- Shawnee
- Widow's Creek

Several of these plants' practiced combined fly and bottom ash ponding. Additionally, Widow's Creek in particular has FGD and was a nominated candidate site.

The individual evaluations by the investigative team led to the conclusion that many of these plants were located in areas of relatively complex hydrogeology. After initial evaluations, visits were undertaken to the Widow's Creek, Kingston, and Colbert plants of TVA. The visits confirmed the initial hydrogeological conclusions of the investigative team. Hence, it was concluded that given the budget and scope of the effort that was allocated at every site, it would not be appropriate to recommend a TVA site.

5.2.2 Mid-Course Corrections on Sulfur Rank and Sulfur Control

In November, 1980, the investigative team also considered the distribution of the more promising sites in terms of sulfur rank (high or low sulfur), particulate control system (bag filter or electrostatic precipitator) and method of sulfur control (lime/limestone, alkaline fly ash, dual alkali, etc.

Sulfur rank has an effect on the anticipated environmental effects of solid waste disposal. For example:

- Ashes from western coals are usually more alkaline. Western coals usually contain lower amounts of sulfur. Eastern coals usually contain higher levels of sulfur and the ashes from such coals tend to be neutral to acidic.
- Some of the low sulfur western coals have self-setting characteristics leading to potentially reduced permeability of the disposed ash.

Particulate collection systems may be either electrostatic precipitators or bag filters. Potential differences could be:

- Bag filters usually have more uniform collection efficiency over a wider range of particle sizes. While at present electrostatic precipitators are the dominant particulate control system, in recent years bag filters have grown significantly and are expected to capture an increasingly larger share of the market. Particularly with the increase in the reliability requirements of FGD systems, if particulate control is required this trend is going to be accelerated.
- Bag filters appear to permit the use of dry handling techniques to a larger extent in coal ash disposal.

The method of sulfur control can be based on one of several systems. As of mid-1980 the FGD practice by the utility was as follows:

Process	Number of Plants
Lime based FGD	12
Limestone based FGD	15
Alkaline Ash based FGD	4
Sodium Carbonate based FGD	2
Dual Alkali based FGD	2
TOTAL	35

Lime and limestone scrubbing appear to be the dominant method of sulfur control and will continue to be so in the foreseeable future. However, it is expected that dry FGD will emerge as an important alternative in the near future, particularly for western coals. Since it was anticipated that no plant employing dry FGD would be operational during the life of this project, it was not possible to consider any site with dry FGD systems.

Table 5.1 (attached herewith) presents some data on the above mid-course evaluation on the candidate and back-up sites.

Two candidate sites were ultimately selected and developed; Elrama, which practices lime scrubbing, and Sherburne County which practices limestone and alkaline fly ash scrubbing, cover a broad range in sulfur control. It was also felt that bag filters are not yet sufficiently widely practiced in the utility industry to be able to obtain sites with bag filters. It was felt desirable to consider an eastern coal based on limestone scrubbing. Duck Creek appeared to be a potentially suitable site. However, budgetary considerations and the fact that Sherburne County does use some limestone (in addition to alkaline ash) scrubbing led to Duck Creek being dropped.

5.2.3 Added Sites

It was felt that in the next few years the conversion of new coal-fired power plants in the relatively arid western part of the country would be very significant. Against this background it was felt that a relatively arid western site, that is a site located in a relatively arid area west of the Continental Divide, would be very worthwhile. With this in mind, a strong effort was undertaken to particularly focus on the relatively arid sites.

The available pool of western sites (that practices coal ash and/or FGD waste disposal under relatively arid conditions) is at present limited. In these sites the environmental impacts would tend to be minimal, particularly those impacts occurring through water-born contaminant migration. Such a site could provide a useful point of comparison for findings on waste/water interaction in other comparable settings. It is noted that the ongoing program of investigations near Center, North Dakota at the Baukol-Noonan mine (originally funded by EPA and now funded by DOE) is one case of mine disposal in a relatively arid area. Such disposal in a mine area may be subject to a comprehensive surface mine regulatory compliance framework. It is also noted that western mine disposal sites would cause some assessment problems due to the relative absence of water and ground water at these sites. The focal point of site development, sampling and analysis in the relatively arid sites may include unsaturated zone phenomena, including the shape of the leachate plume, the rate and extent of plume migration with time, and the extent of contaminant attenuation during plume migration.

Evaluation of the available sites led to the Dave Johnston site being recommended as a candidate site and later selected for development. Although in an area of significant net evaporation, the Johnston site is east of the Divide and in a flood plain. Further evaluation led to Hunter plant of Utah Power and Light being nominated as another relatively arid site west of the

TABLE 5.1

DIVISION OF CANDIDATE AND BACK-UP SITES BY SULFUR RANK, PARTICULATE COLLECTION, AND SULFUR CONTROL SYSTEMS

Plant Information	Number of Plants			
	Candidate	Back-Up	Promising to Date (11-15-80)	Total
Sulfur Rank				
High	4	1	1	5
Medium	5	2	2	7
Low	10	5	5	15
Total	19	8	8	27
Particulate Collection System[a]				
ESP	16	8	7	24
Bag Filters	2	-	-	2
Simultaneous Removal	2	-	1	2
Total	20	8	8	28
Sulfur Control System				
Alkaline Ash (supplemented by lime or limestone as needed)	2	-	1	2
Lime	2	-	1	2
Limestone	4	1	1	5
Sodium Carbonate	-	1	-	1
Total	8	2	3	10

---

[a] In some cases, a plant has more than one collection system. Thus we have 19 plants in candidate list and 20 systems.

Divide. Preparations were made to start preparing a Test Plan on this site. However, Utah Power & Light came to feel that it would not be possible for them to participate in this study at the Hunter site. Hence, it was dropped from further consideration.

Additional evaluations led to Apache Plant of Arizona Electric Power Cooperative being nominated as an arid site west of the Divide. Test Plan preparations were begun after obtaining an indication that the utility would be willing to cooperate. However, by this time considerable budgetary and time constraints led to the decision that the study would be limited to six sites.

5.2.4 Small Plants

Efforts were made to particularly focus on small plants, in particular city or municipal power plant facilities. In view of the desirability of having a small plant for engineering/cost evaluations (small plants would be unable to obtain economy of scale associated with large volumes of coal ash and FGD generated by large plants), the following specific efforts were undertaken:

- Substantial additional contact with American Public Power Association (APPA) was undertaken with a view toward obtaining additional data on small plants.
- Attempts to obtain additional data on small plants west of the Continental Divide also continued.

On balance, the basic problem in terms of small plants is that they usually dispose of their wastes along with other (often non-utility) wastes in a combined manner. Since the scope of this project is limited to coal ash and FGD wastes and from coal fired power plants, evaluating such complex disposal operations was not considered to be within the scope of this project. The interactions with APPA and other efforts failed to reveal a suitable small plant site for the study.

5.3 INDIVIDUAL VISITS

Tables 5.2 and 5.3 summarize the information on the outcomes of the individual visits to both the candidate and back-up sites and additional sites added during the mid-course evaluation studies. Tables 5.2 and 5.3 outline the factors that led to the final selection.

5.4 FINAL SELECTIONS

Table 5.4 summarizes overall data on the six selected sites. A brief account of the important features of each of these is listed below.

Plant Allen, Duke Power Co.

Important factors that led to the selection of the combined fly and bottom ash ponding operation at this plant were:

Page 1 of 2

TABLE 5.2 INDIVIDUAL DISPOSAL SITE VISITS - CANDIDATE AND BACKUP SITES

NO.	PLANT AND UTILITY	DATE OF VISIT	TECHNICAL ASSESSMENT		UTILITY PERCEPTIONS	FINAL ASSESSMENT
			DISPOSAL OPERATION	SITE CONDITIONS		
1	Allen, Duke, Power	March 1980	Combined fly & bottom ash. Very typical of practice in this region.	Outstanding background data. Site very typical of Piedmont region and can be well understood.	Very interested in cooperating in the study.	After EPA approval, Allen was nominated as a test site. After utility approval, Test Plan prepared. Site under evaluation as of Jan. 1981.
2	Arapahoe Public Service of Colorado	Sept. 1980	Fly & bottom ash sent to interim pond (landfill is 30 miles away) in typical practice, but expected to be less prevalent in future.	Understandable hydrogeology at the station and final disposal site at Golden, CO.	Utility feels that their resources are committed to a large EPRI effort at Arapahoe.	After EPA approval it was decided to focus on other sites.
3	Big Brown Texas Utilities	Feb. 1981	Disposal of fly ash (dry) & bottom ash (wet slurry) is on lignite areas.	Understandable hydrogeology & site conditions.	Willing to cooperate in the study.	While the site was doable, Powerton was selected in its category.
4	Jim Bridger Pacific Power & Light	Sept. 1980	Ash disposal is done in "cells" in the mine. All plant liquid wastes are sent to FGD & Evaporation Ponds.	Very difficult area in terms of hydrogeology, located in canyon area.	Willing to cooperate in the study.	Rejected on technical grounds.
5	Clifty Creek Indiana-Kentucky Electric	Sept. 1980	Fly ash ponded in an area converted to a pond by a dam across a creek. Two bottom ash ponds.	Very difficult hydrogeology. Bottom ash area subject to flooding.	Willing to cooperate in the study.	Rejected on technical grounds.
6	Columbia I. Wisconsin Power & Light	Aug. 1980	Fly ash & bottom ash disposal in adjacent unlined ponds. Power plant practice is very modern.	Understandable hydrogeology & site environment.	Willing to cooperate in study.	Test Plan was prepared but dropped due to budgetary constraints and duplication of selected sites of same type with Plant Allen.

TABLE 5.2 INDIVIDUAL DISPOSAL SITE VISITS - CANDIDATE AND BACKUP SITES (continued)

NO.	PLANT AND UTILITY	DATE OF VISIT	TECHNICAL ASSESSMENT		UTILITY PERCEPTIONS	FINAL ASSESSMENT
			DISPOSAL OPERATION	SITE CONDITIONS		
7	Colstrip Montana Power	No Visit	No Visit	No Visit	Utility had other constraints and did not wish to participate.	Rejected on grounds of uncertainty concerning utility cooperation.
8	Comanche Public Service of Colorado	Feb. 1980	Bottom ash to interim ponds. Fly ash to silos & sold to a contractor; utilization of ash approached 40% in 1978.	No site condition assessment from geohydrology viewpoint.	Not investigated.	Rejected on technical ground (ash sold). Dave Johnston was selected in its group.
9	Drake Colorado Springs Dept. of Public Utilities	Sept. 1980	Co-disposal of coal ash with similar wastes from another power plant (Ray Nixon) if a clay substrate landfill.	Moderately complex hydrogeology. Ground water not likely to be encountered. Leachate movement may be very slow.	Not investigated.	Placed on hold. Finally rejected when budgetary constraints cut number of sites.
10	Duck Creek Central Illinois Power & Light	Sept. 1980	Coal ash, FGD wastes & other plant waste ponded. Existing pond will be filled up in 1981. New one planned north of the existing one.	Strip mined area; different but understandable hydrogeology.	Willing to cooperate in the study.	Initially considered for limestone scrubbing of eastern coal. Sherco was selected in its group.
11	Elrama Duquesne Light and Conversion Systems, Inc.	Jan. 1980	FGD was stabilized by Conversion Systems, Inc. & placed in a managed fill 12 miles from power plant.	Area with significant acid mine drainage. Moderately complex hydrogeology.	Both Duquesne Light & Conversion Systems willing to cooperate in the study.	After EPA approved. Elrama was nominated as a Test Site. After Duquesne Light & CSI approved Test Plan, site developed in March 1981.
12	Huntley Niagara Mohawk Power	No Visit	No Visit	No Visit	Not investigated.	Placed on hold and later rejected when Powerton was selected in its group.
13	Dave Johnston Pacific Power & Light	Sept. 1980	Fly ash from Units 1,2, & 3 (and bottom ash after interim ponding) are landfilled. Disposal practice typical.	Plant located in arid area on banks of River Platte. Understandable hydrogeology.	Willing to cooperate in the study.	After EPA approval, Dave Johnston was nominated a Test Site. After PPPL approved Test Plans, site developed in May 1981.

TABLE 5.2 (Cont'd.)

NO.	PLANT AND UTILITY	DATE OF VISIT	TECHNICAL ASSESSMENT		UTILITY PERCEPTIONS	FINAL ASSESSMENT
			DISPOSAL OPERATION	SITE CONDITIONS		
14	Keystone Pennsylvania Electric	Feb. 1981	Fly ash disposal is in accordance with modern practice.	Very complex hydrogeology, mine drainage.	Complex ownership. Approval likely to be complex and time consuming.	Rejected on technical grounds.
15	A. S. King Northern States Power	August 1980	Fly ash and boiler slag to an unlined landfill. A good part of boiler slag is sold (for utilization)	Site on flood plain and is an old gravel pit. Moderately complex hydrogeology.	Complex property ownership. Approval may be complex.	Rejected on technical grounds.
16	George Neal Iowa Public Service	No Visit	No Visit	No Visit	Not investigated.	Allen selected in its group and hence this was dropped.
17	Powerton Commonwealth Edison	Sept. 1980	Fly & bottom ash disposal in lined landfill is a modern practice. Old site with 8" of line and new site with 60" of line.	Understandable hydrogeology.	Willing to cooperate in the study.	After EPA approval, Powerton nominated as a Test Site. After utility approved, Test Plan started. After State approval, site developed in November, 1981.
18	Presque Isle Upper Peninsula Generating	July 1980	Plant in transition from old landfill to a new site in mid 1980.	Hydrogeologically the old landfill is an excellent site.	Willing to cooperate	Powerton was selected in its group and hence this one was dropped.
19	Lansing Smith Gulf Power	Oct. 1980	Smaller plant practiced combined fly and bottom ash ponding. Pond water is recycled and reused.	Coastal setting & understandable hydrolgeology.	Willing to cooperate.	After EPA approval, Smith was nominated a Test Site. After utility approval of Test Plan, site developed in December, 1981.
20	Sherburne County Northern States Power	Aug. 1980	Fly ash and FGD waste in a lined pond is a typical practice.	Moderately complex hydrogeology.	Willing to cooperate in the study.	After EPA approval, Sherburne Co. was nominated as a Test Site. After utility approval of Test Plan, site developed in August, 1981.
21	Southwest Station Springfield City Utilities	No Visit	No Visit	No Visit	Not investigated.	Selection of Elrama disposing of stabilized FGD wastes and later budgetary constraints led to this site being dropped.

TABLE 5.2 (Cont'd.)

NO.	PLANT AND UTILITY	DATE OF VISIT	TECHNICAL ASSESSMENT		UTILITY PERCEPTIONS	FINAL ASSESSMENTS
			DISPOSAL OPERATION	SITE CONDITIONS		
22	Sporn Central Operating	No Visit	No Visit	No Visit	Not investigated.	Columbia I and Allen were selected in its group. Later Columbia I was dropped due to budgetary constraints.
23	Sutton Carolina Power & Light	Oct. 1980	Typical combined fly and bottom ash disposal by ponding.	Coastal setting. Understandable but moderately complex hydrogeology.	Not particularly willing to participate in the study.	Smith was selected in its group and this was dropped.
24	Tombigbee Alabama Electric Coop.	Oct. 1980	Fly and bottom ash to a pond. Limestone based FGD waste to a lined pond.	Potential hydrogeology complications with the effect on groundwater movement by changes in river level.	Willing to cooperate in the study.	Budgetary constraints and the fact that FGD ponding by itself is not a major future practice led to this site being dropped.
25	Widow's Creek Tennessee Valley Authority	May 1980	FGD wastes ponded, coal ash separately ponded in an adjacent pond.	Primarily located in residual soil and limestone bedrock. Very complex hydrogeology.	Willing to cooperate in the study.	Rejected on technical grounds.
26	Winyah South Carolina Public Service Authority	No Visit	No Visit	No Visit	Not willing to cooperate in the study.	Tombigbee and Smith were the alternatives and were available.

TABLE 5.3 OTHER SITE VISITS - MIDCOURSE ADDITIONS

NO.	PLANT AND UTILITY	DATE OF VISIT	TECHNICAL ASSESSMENT		UTILITY PERCEPTIONS	FINAL ASSESSMENTS
			DISPOSAL OPERATION	SITE CONDITIONS		
1	Colbert Tennessee Valley Authority	May 1980	1420 mw plant, started in 1955. Combined fly and bottom ash ponding.	Very complex hydrogeology with limestone and shale over clayey soils.	Willing to co-operate in the study.	Rejected on technical ground. Allen was selected as representative of fly and bottom ash ponding.
2	Kingston Tennessee Valley Authority	May 1980	1723 mw plant, started in 1954. Combined and bottom ponding.	Residual soil and weathered bedrock lead to complex hydrogeology.	Willing to co-operate in the study.	Rejected on technical grounds. Allen was selected as representative of fly and bottom ash ponding.
3	Hunter Utah Power & Light	April 1981	800 mw plant, started in 1978. Modern plant practices co-disposal of fly ash, bottom ash and dewatered FGD wastes in a managed fill.	Arid western setting alkaline soil and understandable hydrogeology.	Not willing to co-operate in study.	Dropped after extensive preparation for a Test Plan due to utility decision not to participate.
4	Apache Arizona Electric Power Co-Op	Sept. 1981	465 mw plant practices ponding of ash and limestone based FGD wastes.	Very arid site with alkaline soils and understandable hydrogeology.	Willing to co-operate in the study.	Apache was nominated as the 7th site. However, budgetary and time constraints led to EPA decision not to proceed with a 7th site.
5	West Penn Power	April 1981	448 mw plant started in 1963. Coal ash disposed in a managed fill.	Complex hydrogeology. Area has been extensively deep mined.	Not investigated.	Rejected on technical grounds.

- Combined ponding disposal practice is the most common single practice in the U.S. today and practically the only disposal mode in the Piedmont Region.

- The amount of precipitation and the mix of residual and alluvial soils at this site represent environmental conditions typical of many other locations in the eastern half of the U.S.

- The utility practice of co-disposal of intermittent contaminant wastes such as boiler cleaning wastes and coal pile runoff in ash ponds may have mitigative features. Further it is widely practiced by others and has potentially broad applicability in the future.

Elrama, Duke Power and Conversion Systems Inc.

Flue gas cleaning waste disposal by stabilization process is likely to be a more important disposal option in the future. This site was selected for the following reasons:

- Landfilling of stabilized FGD wastes was available only at a few sites in 1980 but was a planned commitment at many other interior locations in the eastern U.S. The type of stabilization practiced at Elrama is based on a controlled mixing of FGD scrubber wastes with lime, fly ash, and other substances to change the waste from a thick slurry to a soil-like material that can be placed in managed fill.

- Land disposal of flue gas cleaning wastes in abandoned strip mines is also a growing practice. The Elrama site occupies an abandoned coal mining area that exhibits acid mine drainage. While acid drainage is a complicating factor in the environmental assessment, this situation represents an opportunity to fill a significant data gap on this method of waste disposal in a typical acid mine drainage setting.

Dave Johnston, Pacific Power & Light

The following factors were important in the selection of the fly ash and bottom ash landfill at the Dave Johnston site:

- The site is in a western setting where the rate of growth of new coal-fired capacity is likely to be significant.

- The setting combines significant net evaporation in a flood plains location that would be expected to illustrate contaminant migration potential in an identifiable pattern.

- The disposal in a managed fill is fairly typical of the dry handling/landfill method.

Sherburne County, Northern States Power

The important factors that led to the selection of Sherburne County as a site for detailed evaluations were:

- The waste management practice involves removal of sulfur oxides in the stack gases by alkaline fly ash and limestone. Additionally, this plant practices forced oxidation of the FGD waste to produce a material relatively rich in calcium sulfate that dewaters well.
- The environmental setting is isolated from other sources of potential contamination and combines modest precipitation, relatively permeable underlying soils supporting locally high quality groundwater, and temperature extremes.

Powerton, Commonwealth Edison

The following factors were important in the selection of the ash landfill operation at Powerton:

- The type of ash collection, handling and disposal in a managed landfill practiced at Powerton is one of the growing practices in the utility industry nationwide.
- The Powerton site provides an opportunity to study the effects of landfill disposal of coal ash from a western coal in a typical interior climatic and geohydrologic settings.
- This is a site with an artificial lining made of Poz-o-Pac and would provide an opportunity to study the effect of lining.
- The completed landfill is bordered along one downgradient face by a small permanent stream (Lost Creek). This would permit an opportunity to study nonpoint source drainage impacts of coal ash disposal on both groundwater quality and water quality in a small surface water body.

Lansing Smith, Gulf Power

The important factors that led to the selection of Lansing Smith were:

- The disposal practice employed at Lansing Smith is very typical of those in the coastal areas. Combined ponding of fly and bottom ash in an unlined pond is likely to continue as a prevalent disposal practice on the Atlantic and Gulf coasts.
- The disposal operation includes recycle and reuse of the water employed for conveyance of fly ash and bottom ash.
- This is a truly coastal site within the zone of tidal influence directly occupying a tidal interface between the saline waters and

the acidic fresh water swamps. The area has heavy precipitation and pervious, sandy soils.

- This site is typical of what might be a growing type of practice if the conversion to coal from other forms of fossil fuel is accelerated along the Atlantic and the Gulf coasts.

Exhibit A

SCOPE OF THE PROJECT

TITLE:	Characterization and Environmental Monitoring of Full-Scale Utility Waste Disposal Sites
EPA CONTRACT NO.:	68-02-3167
TIME PERIOD:	October 1, 1979 to December 31, 1981
EPA PROJECT OFFICER:	Julian W. Jones (Tel. 919/541-2489)
PRIME CONTRACTOR:	Arthur D. Little, Inc.
ADL PROJECT MANAGER:	Chakra J. Santhanam (Tel. 617/864-5770)

This project will obtain sufficient data and information to enable the EPA to determine the extent, if any, to which coal ash & FGD waste disposal has to be managed to protect human health and the environment.

This study will involve environmental monitoring, data gathering, and economic assessments of disposal practices at approximately twelve sites at various locations around the country. Results from the study will provide the technical background data and information needed to determine the degree to which disposal of these wastes needs to be managed in order to protect human health and the environment.

The project consists of three major tasks and a supporting task. Figure A.1 is the overall information flow diagram showing the interrelationship of these task. Task I, the initial screening of sites and preparation of Preliminary Test Plans, began at the outset of the project. The work in Task I resulted in a set of disposal sites for detailed evaluation. These sites are now under evaluations.

Work in Task II consists basically of two efforts -- first, finalization of Test Plans for each site, including revised cost estimates, where appropriate, for site evaluations based on a more detailed study of the sites; and, second, the performance of site evaluations, including disposal site and waste characterization, environmental monitoring, and the obtaining of capital and operating cost information on FGC waste disposal. The finalization of Preliminary Test Plans begun during Task I will continue into Task II. The actual process of arriving at the final set of sites may require to some extent an iterative procedure involving interfaces to achieve utility cooperation, the review of recommended sites and alternatives, the preparation of Preliminary Test Plans and finalization of the latter.

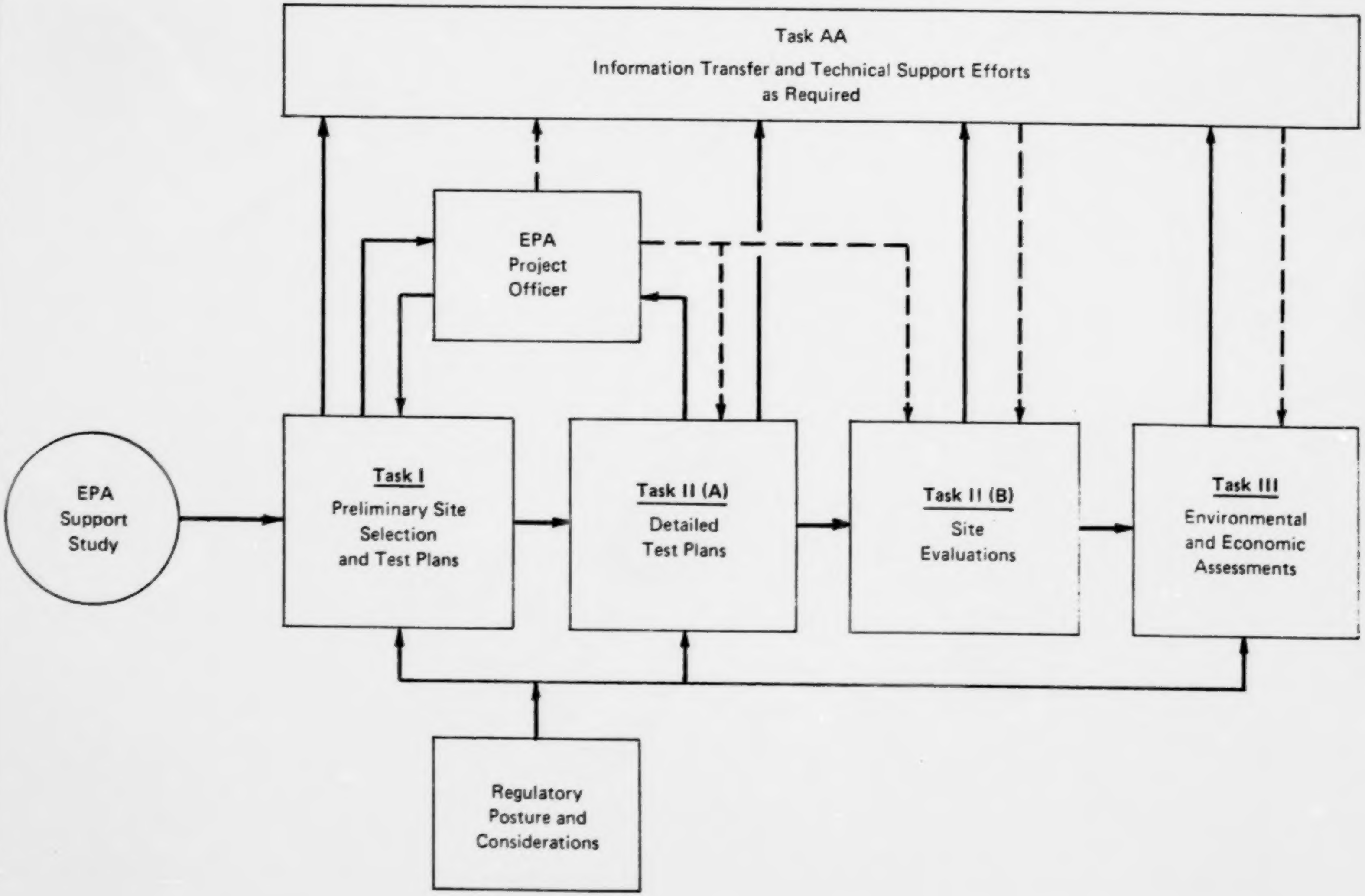

Task AA
Information Transfer and Technical Support Efforts as Required
EPA Project Officer
EPA Support Study
Task I
Preliminary Site Selection and Test Plans
Task II (A)
Detailed Test Plans
Task II (B)
Site Evaluations
Task III
Environmental and Economic Assessments
Regulatory Posture and Considerations

FIGURE A.1 OVERALL PROJECT INFORMATION FLOW DIAGRAM

10 Lines to End of Typing Area

For Page Numbering
ADL 054-476-200M

Major work under Task III, which involves the environmental and economic assessments and the formulation of recommendations, will be initiated near the middle of Task II as site evaluations proceed. The work under Task III is scheduled to continue for two months beyond the completion of field sampling and analyses.

The objective of Task III is to assist the EPA by developing data and information on the environmental effects of coal ash and FGD waste disposal and engineering/cost estimate on the handling of disposal of these wastes. This task is the one under which that objective is to be achieved, based on the planning and data collection accomplished in Tasks I and II. Specifically, the data from Task II will be assessed in three categories of evaluation:

- environmental assessment,
- assessment of disposal operations, and
- engineering/cost of disposal.

These assessments will all provide input into the formulation of a series of recommendations concerning the sound practice for the disposal of these wastes. In addition to the work in these three tasks, a separate task (Task AA) has been included in theproject to provide general assistance to EPA in the dissemination of information relating to the work performed in this project and to provide specific technical efforts, as requested by EPA.

Exhibit

Exhibit B

ADVISORY COMMITTEE

Mr. William Becker
American Public Power Association
2600 Virginia Ave., NW
Washington, D. C. 20037

Mr. John M. Heffelfinger
U. S. Environmental Protection Agency
Office of Solid Waste (WH-565)
401 M Street, SW
Washington, D. C. 20460

Mr. Christopher F. Hughes and Mr. Corey Tranch
Edison Electric Institute
Environmental Project Manager
1111 Nineteenth St., NW
Washington, D. C. 20036

Mr. Kurt Jakobson
U. S. Environmental Protection Agency
Office of Environmental Engineering
and Technology (RD-681)
Washington, D. C. 20460

Mr. Val Weaver
U. S. Department of Energy
Office of Fossil Fuel Utilization
Washington, D. C. 20545

Mr. C. J. Santhanam
Arthur D. Little, Inc.
Acorn Park
Cambridge, Mass. 02140

Mr. Julian W. Jones
MD-61
Industrial & Environmental Research Laboratory
U. S. Environmental Protection Agency
Research Triangle Park, NC 27711

Exhibit B
(Continued)

TECHNOLOGY COMMITTEE

Mr. Dave Anderson
Duke Power Company
P. O. Box 2178
Charlotte, NC 28242

Mr. Jerry Bindle
Union Electric Company
P. O. Box 149, Mail Code 450
St. Louis, MO 63166

Mr. Bob Clough
Northern States Power Company
414 Nicollet Mall
Minneapolis, MN 55401

Dr. H. P. Flora
Tennessee Valley Authority
470 Commerce Union Bank Bldg.
Chattanooga, TN 37401

Mr. Ed Gladbach
Los Angeles Department of Light & Power
P. O. Box 111
Room 1034
Los Angeles, CA 90051

Mr. Dean Golden
Electric Power Research Institute
P. O. Box 10412
3412 Hillview Ave.
Palo Alto, CA 94304

Mr. John M. Heffelfinger
U. S. Environmental Protection Agency
Office of Solid Waste (WH-565)
401 M Street, SW
Washington, D. C. 20460

Mr. Jack Keeley
U. S. Environmental Protection Agency
Robert S. Kerr Environmental
Research Laboratory
P. O. Box 1198
Ada, OK 74820

Exhibit B
(Continued)

Dr. Eugene P. Meier
U. S. Environmental Protection Agency
Environmental Monitoring & Support Laboratory
P. O. Box 15027
Las Vegas, NV 89114

Mr. Ron Morrison
American Electric Power Service Corp.
P. O. Box 1986
301 Virginia St., East
Charleston, WV 25327

Mr. Randall E. Rush
Southern Company Services, Inc.
P. O. Box 2625
800 Shades Creek Parkway
Birmingham, Al 35202

Mr. Norbert B. Schomaker
Environmental Protection Agency
MERL-CINN
26 W. St. Clair Street
Cincinnati, Ohio 45268

Mr. C. J. Santhanam
Acorn Park
Arthur D. Little, Inc.
Cambridge, Mass. 02140

Mr. Julian W. Jones
MD-61
Industrial & Environmental Research Laboratory
U. S. Environmental Protection Agency
Research Triangle Park, NC 27711

USE THIS SHEET FOR REPORT TYPING

TOP

EXHIBIT C

REGIONAL DIVISION OF THE UNITED STATES

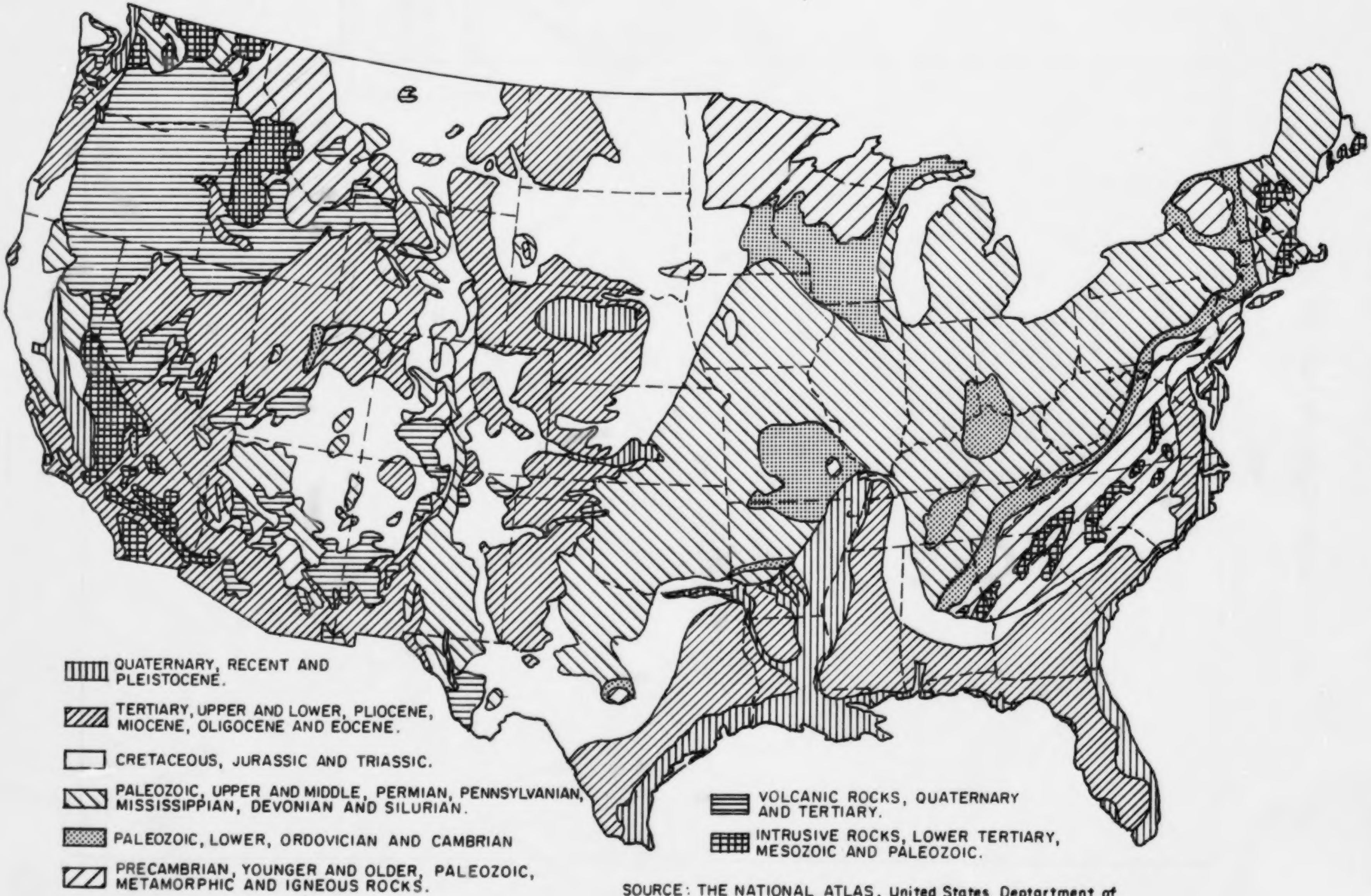
The United States was divided into 14 regions (as shown in Figure 2.2 in the main text) for the purpose of obtaining a manageable number of plants for evaluation by the site selection team. On the basis of this, the number of candidate sites selected in each region could be in proportion to the number of plants in that region. A logical basis for this division was sought so that the division itself could serve to identify plants at which the physical characteristics of the sites were broadly similar. Similarities in disposal practices, geologic conditions, surficial soil conditions, and climatic factors were considered.

Generally, the regions selected for this study correspond to groupings of one or more physiographic regions in the United States (see Figures C-1 and C-2). Physiographic regions have been defined by a number of investigators, including Hunt(3), Fenneman(4,5), and Thornbury(6). Standard reference works, such as the four sources mentioned, were consulted to define the physiographic provinces. These provinces are grouped into 11 major divisions. Each province has characteristics peculiar to itself in that a distinctive geological framework is present which gives rise to distinctive land forms. The land forms express the influences of the structural geologic parent materials, weathering effects, erosion and sedimentation, and climatic factors. In general, each province has a distinctive climate, particular vegetative types, characteristic soils, a particular water regime, and differences in principal natural resources. For the most part, each physiographic province also has its own economy and numerous distinctive cultural traits. These provinces thus form a good basis for the division of the United States for purposes of this study. Climatic factors (temperature, gross and net precipitation, and frost penetration) are generally similar throughout a given province, although some provinces display significant differences where the geologic framework has been a predominant influence on the formation of present day land forms. Figure C-3 outlines temperature ranges, while Figure C-4 shows some frost penetration data. Figures C-5 and C-6 show gross and net precipitation, and Figure C-7 presents runoff data.

10 Lines
to End of
Typing Area

The division of the United States into regions for this study has been made for convenience in managing a large number of potential investigation sites and to identify areas of the country in which conditions are generally similar with respect to hydrogeologic and geotechnical aspects. Where only a few power plants existed in a physiographic province, these provinces have been combined into larger regions. For example, the Pacific Border Province and the Sierra-Cascade Province were combined into Region M because of the scarcity of power plants in that area. Also, the Appalachian Plateaus Province, the Valley and Ridge Province, and the Blue Ridge Province were combined into Region B because of similarities in conditions at the power plants. In this instance, similarities in disposal practice and plant operating characteristics appeared to overshadow the geologic differences between the physiographic provinces. In some cases,

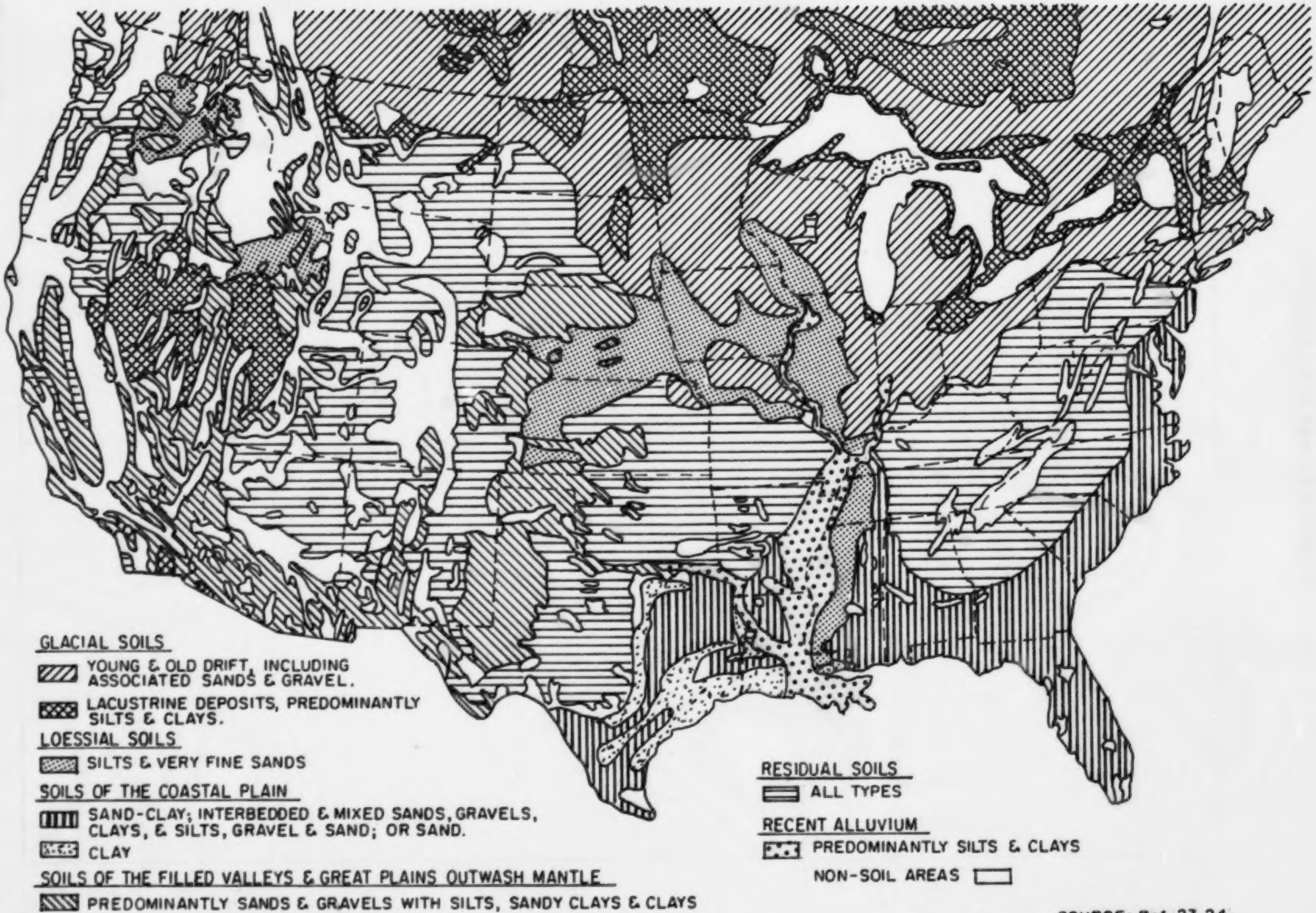
For Page Numbering



QUATERNARY, RECENT AND PLEISTOCENE.
TERTIARY, UPPER AND LOWER, PLIOCENE, MIOCENE, OLIGOCENE AND EOCENE.
CRETACEOUS, JURASSIC AND TRIASSIC.
PALEOZOIC, UPPER AND MIDDLE, PERMIAN, PENNSYLVANIAN, MISSISSIPPIAN, DEVONIAN AND SILURIAN.
PALEOZOIC, LOWER, ORDOVICIAN AND CAMBRIAN
PRECAMBRIAN, YOUNGER AND OLDER, PALEOZOIC, METAMORPHIC AND IGNEOUS ROCKS.
VOLCANIC ROCKS, QUATERNARY AND TERTIARY.
INTRUSIVE ROCKS, LOWER TERTIARY, MESOZOIC AND PALEOZOIC.

SOURCE: THE NATIONAL ATLAS, United States Deptartment of the Interior Geological Survey, Washington, D.C., 1970

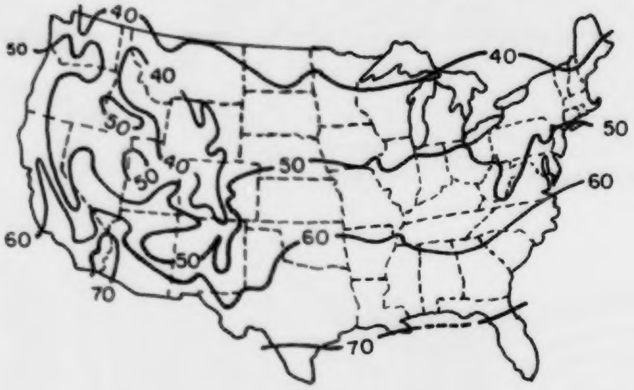
FIGURE C-1 GEOLOGIC MAP OF THE UNITED STATES.


GLACIAL SOILS
▨ YOUNG & OLD DRIFT, INCLUDING ASSOCIATED SANDS & GRAVEL.
▩ LACUSTRINE DEPOSITS, PREDOMINANTLY SILTS & CLAYS.
LOESSIAL SOILS
▒ SILTS & VERY FINE SANDS
SOILS OF THE COASTAL PLAIN
▥ SAND-CLAY; INTERBEDDED & MIXED SANDS, GRAVELS, CLAYS, & SILTS, GRAVEL & SAND; OR SAND.
░ CLAY
SOILS OF THE FILLED VALLEYS & GREAT PLAINS OUTWASH MANTLE
▧ PREDOMINANTLY SANDS & GRAVELS WITH SILTS, SANDY CLAYS & CLAYS
RESIDUAL SOILS
▤ ALL TYPES
RECENT ALLUVIUM
⁘ PREDOMINANTLY SILTS & CLAYS
NON-SOIL AREAS ☐

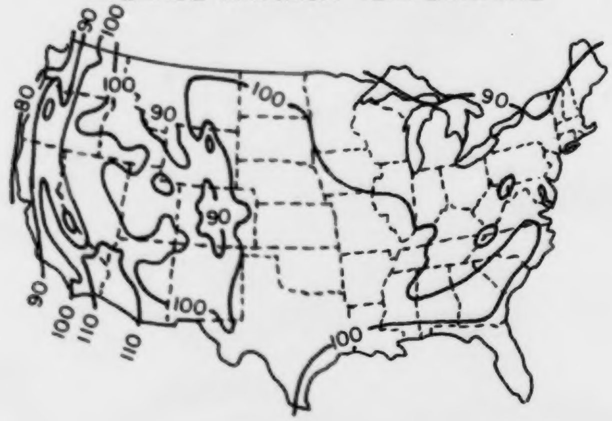
SOURCE: Ref. 23,24

FIGURE C-2 SOIL DEPOSITS OF THE UNITED STATES AND CANADA.

AVERAGE ANNUAL TEMPERATURE


40
50
40
40
50
50
50
40
50
50
60
60
60
50
70
70

AVERAGE MAXIMUM TEMPERATURE


90
100
80
100
90
100
90
60
90
90
100
110
110
100
100

AVERAGE MINIMUM TEMPERATURE

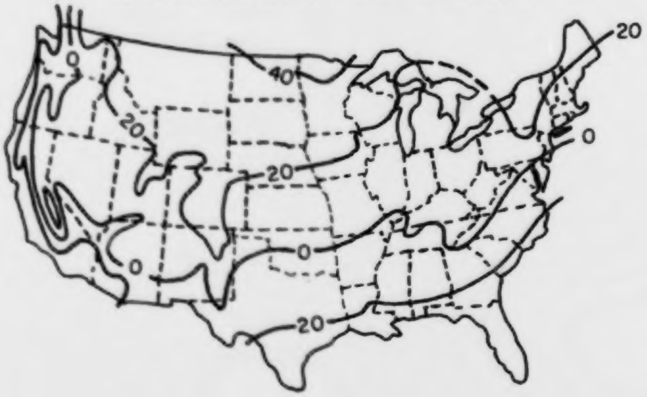
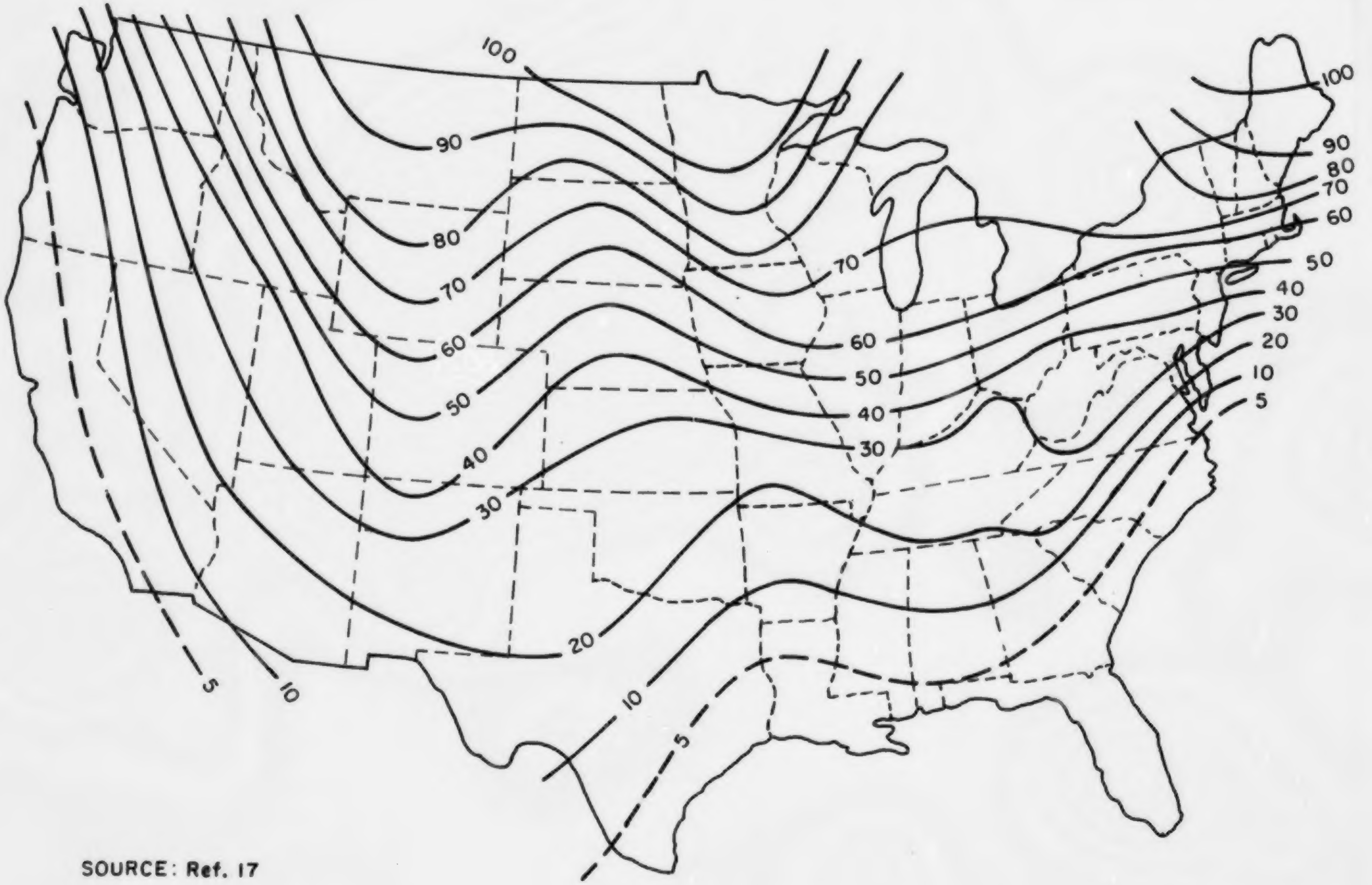

20
0
40
20
20
0
0
0
20

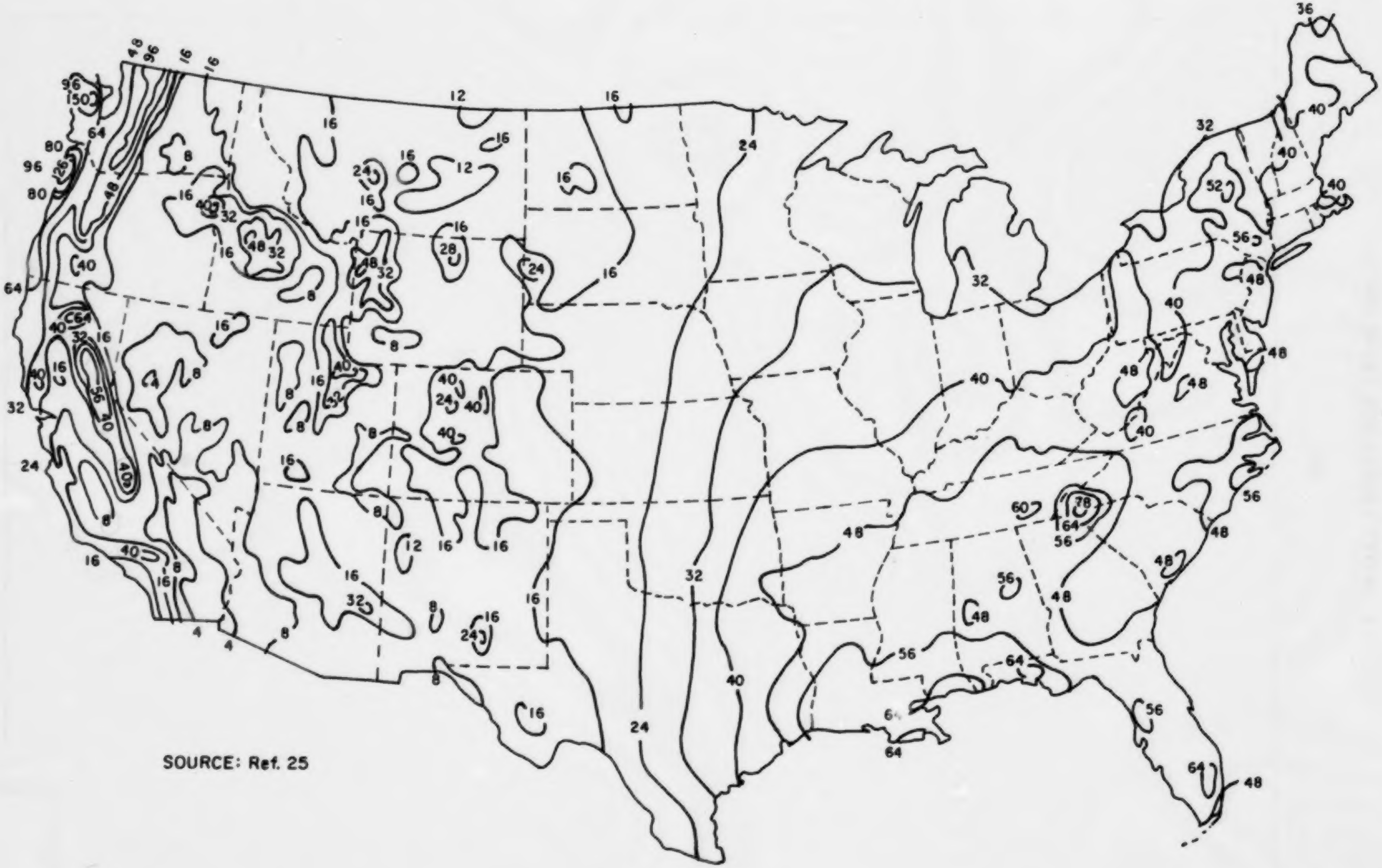
FIGURE C-3 TEMPERATURE DATA MAP


100
90
80
70
60
50
40
30
20
10
5
100
90
80
70
60
50
40
30
20
10
5
70
60
50
40
30
100
90
80
70
60
50
40
30
20
10
5
10
5

SOURCE: Ref. 17

FIGURE C-4 MAXIMUM DEPTH OF FROST PENETRATION (in inches) IN THE UNTED STATES.

For Page Numbering

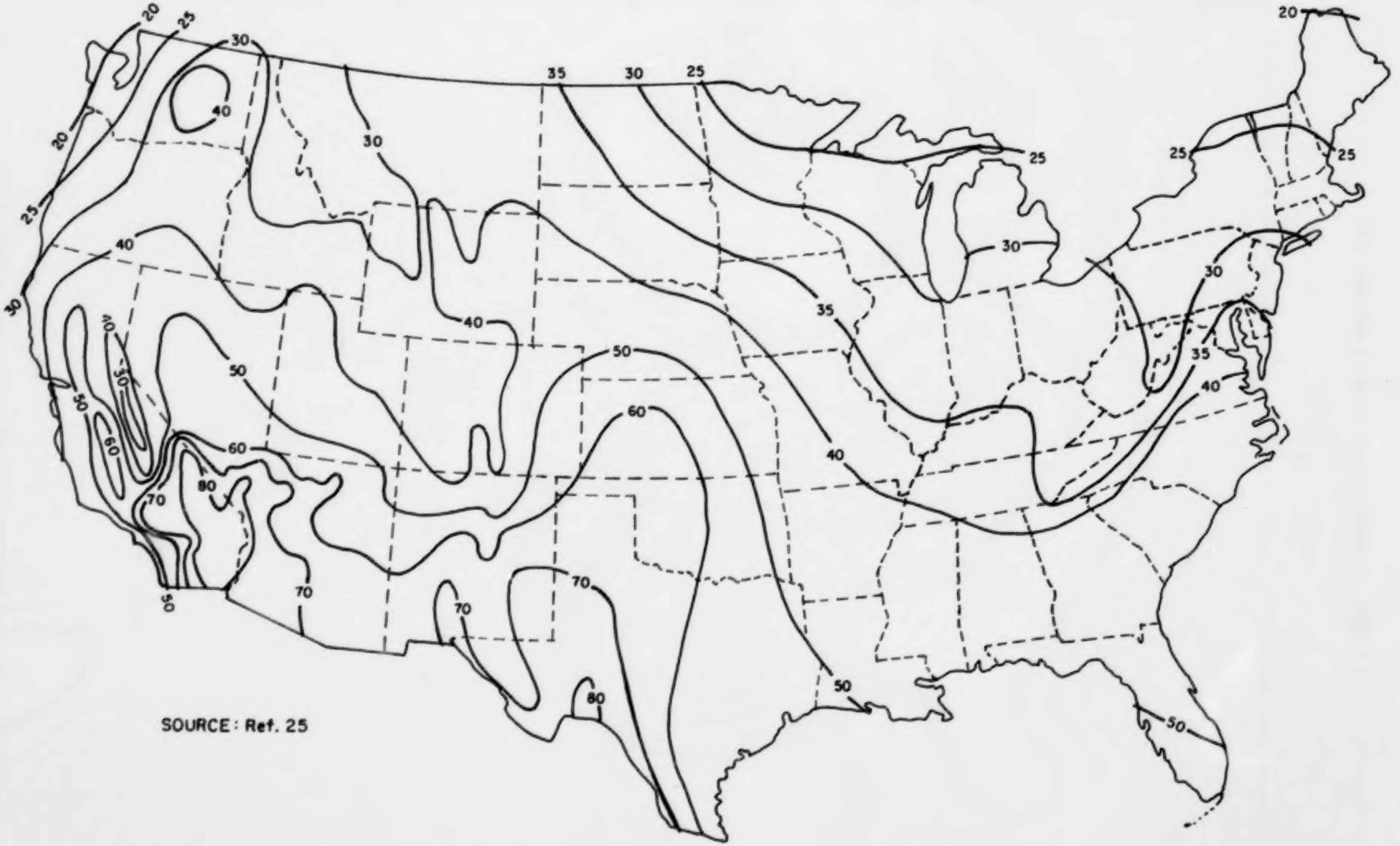


SOURCE: Ref. 25

FIGURE C-5 AVERAGE ANNUAL PRECIPITATION (in inches) IN THE UNITED STATES.

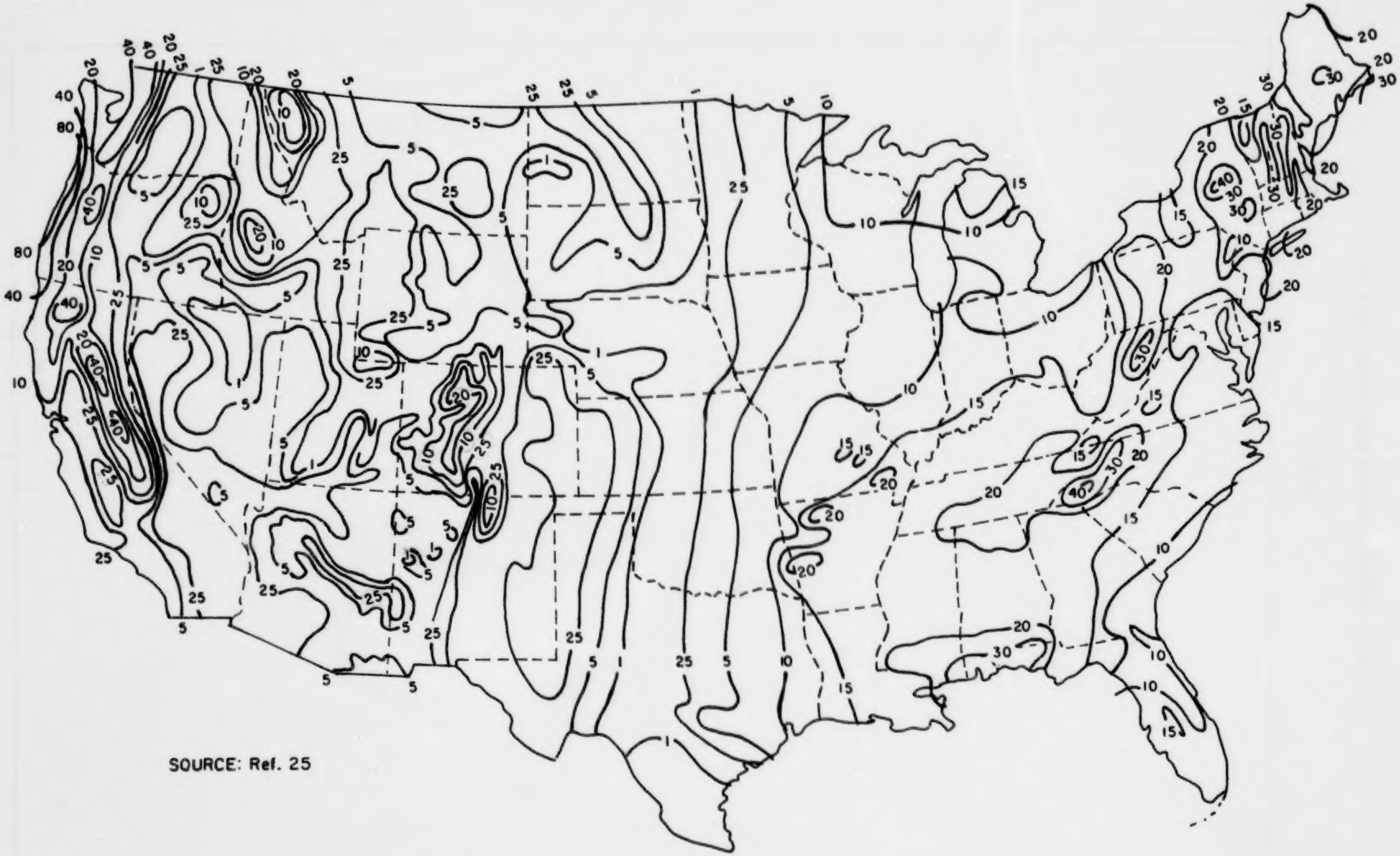
For Page Numbering

ADL 054 1270 200M


20
25
30
40
20
25
30
30
40
40
50
30
50
60
60
70
80
50
70
70
70
80
35
30
25
25
35
50
60
40
50
30
35
40
50
20
25
25

SOURCE: Ref. 25

FIGURE C-6 AVERAGE ANNUAL LAKE EVAPORATION (in inches) IN THE UNITED STATES.



SOURCE: Ref. 25

FIGURE C-7 NORMAL ANNUAL RUNOFF (in inches) IN THE UNITED STATES.

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

physiographic provinces were divided because of their large size and because of significant variations in climatic factors within the province. For example, the Coastal Plain Province was divided into a Gulf Coastal Plain Region (Region A1) and an Atlantic Coastal Plain Region. The Atlantic Coastal Plain Region was combined with the Piedmont physiographic province as Region A2.

Gulf Coastal Plain - Region A1

The Gulf Coastal Plain includes portions of Texas, Arkansas, and Tennessee, a very slight portion of western Kentucky, all of Louisiana, the southwestern quarter of Georgia, and all of Florida. The Gulf Coastal Plain is characterized by shores with mostly sandy beaches backed by estuaries and marshes with mud flats near the mouth of the Mississippi River. Some limestone bluffs are found at the surface on the West Coast of Florida. Inland ridges parallel the coast but altitudes within the Gulf Coastal Plain are generally less than about 150 meters (500 feet). Overall, the Gulf Coastal Plain is a broad plain rising inland. The geologic deposits characteristic of the Gulf Coastal Plain include Quaternary sedimentary deposits along the coastline from southern Texas to western Florida. Generally, these deposits are marine sedimentary deposits along the coast, although along the Mississippi River Valley northward through Louisiana, Arkansas, and into western Kentucky, the Quaternary sedimentary deposits are alluvial materials deposited by the Mississippi River. Inland from these deposits, sedimentary rocks constitute the bedrock units with Tertiary marine sediments gradually giving place to Cretaceous sedimentary marine deposits further inland. Near the coastal zones, the soils are primarily sandy coastal deposits with some undifferentiated areas of sands, silts, and clays. Inland from the coastal regions, the soils consist primarily of residual soils developed from the sedimentary bedrocks.

The Gulf Coastal Region is characterized by average annual temperatures between 18 and 21°C (65 and 70°F) and average annual precipitation which increases from approximately 64 cm (25 in.) per year in southern Texas to more than 150 cm (60 in.) per year in western Florida and southern Alabama. Frost penetration generally is less than one inch throughout most of the Gulf Coastal Region except for the northward extension of the region along the Mississippi River Valley where it increases to approximately 38 cm (15 in.) in western Kentucky. Maximum temperatures in the Gulf Coastal Region often exceed 38°C (100°F), while minimum temperatures rarely go below -7°C (20°F). The exception is along the Mississippi River Valley where minimum average annual temperatures of approximately -15°C (5°F) are found at the northernmost extension of the province in western Kentucky. In general, this region is a moist, warm area characterized by sedimentary bedrock units overlain by coastal soils near the Gulf of Mexico and overlain by residual soils or stream alluvium further inland from the coast. Alluvium generally is found throughout the Mississippi River Valley and along other major rivers in the region such as the Trinity River in Texas, the Red River in Louisiana, and the Tombigbee River in Alabama.

10 Lines
to End of
Typing Area

For Page Numbering

ADL-054-1279-200M

USE THIS SHEET FOR REPORT TYPING (8-1/2 x 11)

TOP

Piedmont and Coastal Plain - Region A2

Region A2 consists of the Atlantic Coastal Plain and the Piedmont Province. This region includes most of Georgia, all of South Carolina, most of North Carolina (except for the westernmost portions which are in the Blue Ridge Province), and the eastern portions of Virginia and Maryland. The Atlantic Coastal Plain is quite similar to the Gulf Coastal Plain in that Quaternary sedimentary deposits are generally found within 32 kilometers (20 miles) of the Atlantic Coast and extend inland as much as 170 kilometers (100 miles) in some areas. Inland from the Quaternary sedimentary deposits are Tertiary marine sedimentary bedrock and Cretaceous sedimentary formations of marine origin. The Atlantic Coastal Plain is quite similar to the Gulf Coastal Plain except that temperatures are more moderate and rainfall is less. Generally, the land surface slopes to the northeast and in the northern portion of the region the valleys are tidal estuaries.

The Piedmont is separated from the Atlantic Coastal Plain by the fall line. Generally, the Piedmont is a rolling upland whose surface slopes to the northeast like the Coastal Plain with altitudes ranging from approximately 610 meters (2000 ft) in the south to somewhat less than 150 meters (500 ft) in the northern portion of the region. In general, the Piedmont Region is underlain by metamorphic rocks, and of Paleozoic sedimentary units. Average annual temperatures in this region vary from approximately 18°C (65°F) in the southernmost portions of Region A2 to approximately 13°C (55°F) in the northern portion, near the Chesapeake Bay area. Annual average precipitation varies from approximately 115 cm (45 in.) in the northern portion of the region to about 140 cm (55 in.) per year in the southern portion. Average maximum temperatures throughout the region are approximately 38°C (100°F) and minimum temperatures generally increase from approximately -12°C (10°F) in the northern portion of the region, near Chesapeake Bay, to approximately -7°C (20°F) in Georgia. Frost penetration increases from approximately one inch per year in southern Georgia to approximately 46 cm (18 in.) per year in the extreme northern portions.

Appalachian - Region B

10 Lines to End of Typing Area

Region B includes the Appalachian Plateaus, the Valley and Ridge Province, and the Blue Ridge Province. The Appalachian Plateaus generally slope westward and are deeply incised by winding stream valleys. Local relief is severe in many cases. Steep hillsides rise to elevations of as much as 915 m (3000 ft). The surface elevation generally varies from 610 m to 915 m above mean sea level. Eastward of this plateau, which extends from northern Alabama into southern New York, the Valley and Ridge Province borders the Appalachian Plateaus. The Valley and Ridge Province consists of parallel valleys and mountainous ridges with altitudes mostly between 305 to 915 m above mean sea level. The parallel ridges trend from southwest to northeast from northern Alabama into eastern Pennsylvania. In general, the altitudes in the Valley and Ridge Province decrease to the northeast. The Blue Ridge Province portion of Region B consists essentially of the easternmost ridge of the Appalachian Highlands and altitudes in this mountainous area often exceed 1525 m above mean sea level.

ADL-054 1279 200M

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

The bedrock units below the surface in Region B consist of upper Paleozoic formations of Mississippian, Pennsylvanian, and Permian Age beneath the Appalachian Plateaus Province, except for the far northern portion, and lower Paleozoic and metamorphosed sediments in the Valley and Ridge and Blue Ridge Provinces. The lower Paleozoic formations include sedimentary deposits, mostly of marine origin, which vary in age from Cambrian sediments to Devonian units. Considerable metamorphism and structural realignment has occurred in the formation of the Appalachian Mountains, with the result that metamorphosed materials often exist in close proximity to severely displaced sedimentary units. In general, the Appalachian Plateaus are underlain by marine sedimentary deposits which are not severely metamorphosed. The surficial deposits in these areas consist of residual soils developed from the underlying sedimentary and metamorphosed bedrocks, except that local alluvial deposits are found along the deeply incised streams which cut through the region.

The average annual temperatures in Region B vary from approximately 16°C (60°F) in northern Alabama, at the southern extremity of the region, to approximately 7°C (45°F) in southern New York at the northern extremity of the region. Average annual rainfall varies from approximately 100 cm (40 in.) per year in the northern portion of the region to about 140 cm (55 in.) per year in the southern portion of the region. The severe relief in this mountainous region of the United States, however, produces local extremes of precipitation and climatic variations. Maximum temperatures in this region vary from approximately 38°C (100°F) in northern Alabama, at the southern extremity of the region, to about 35°C (95°F) in the northern portions of the region. Average minimum temperatures vary from approximately -26°C (-15°F) in the northern portion to approximately -18°C (0°F) in the southern portion of the region. Frost penetration increases from approximately 25 cm (10 in.) per winter season in northern Alabama to as much as 100 cm (40 in.) during a winter season in southern New York. The northern extremity of the region, in New York State, is also characterized by metamorphosed Paleozoic rock units.

New England - Region C

10 Lines to End of Typing Area

Region C includes the New England Province and is generally defined by the Hudson River Valley, although the region has been extended to include the State of New Jersey. In general, the bedrock units in this region consist primarily of metamorphosed Paleozoic rocks. Much of the region has been glaciated and surficial land forms reflect the influence of this glaciation. Residual soil units are not nearly as common in New England as in previously mentioned unglaciated regions of the United States. Alluvial deposits are present only along major streams in the region and they are somewhat overshadowed by the glacial deposits of the region. The average annual precipitation in this region is 100 to 115 cm of rainfall and frost penetration throughout the region exceeds 100 cm per winter season on average. Minimum average temperatures may fall well below -29°C (-20°F) and average maximum temperatures may reach 32°C (90°F). Average annual temperatures are approximately 5°C (40°F) throughout much of this region. This region is characterized by metamorphosed, structurally rearranged bedrock units beneath very thin residual soil covers or deposits of glacial origin of varying thickness and character.

ADL 054-1279-200M

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

Interior Lowlands - Region D

Region D includes all of the Interior Low Plateaus Province and much of the Central Lowland Province. Within Region D are included the western two-thirds of Ohio (the eastern third of the state is in Region B), all of Indiana, all of Illinois, all of Iowa, the northern one-third of Missouri, and approximately two-thirds of Kentucky (eastern Kentucky is in Region B and the far western portion is in Region A1). In general, this region is underlain by bedrock units of Paleozoic age consisting of lower Paleozoic Ordovican, Silurian, and Devonian sedimentary rock units in western Ohio, Indiana, central Kentucky, and portions of northern Illinois and Iowa, and upper Paleozoic Mississippian and Pennsylvanian units throughout the remainder of the region. In general, these are relatively flat-lying sedimentary rock units consisting of shales, limestones, and some sandstones in the Ordovican through Mississippian units and considerable amounts of limestone, sandstone, shale, and coal in the Pennsylvanian units. For the most part, these rock units are overlain with thick residual soils and deposits of thick alluvium in those portions of the region which have not been glaciated. Thick deposits of glacial alluvium also exist along streams in this region, particularly the Ohio, Mississippi, and Illinois rivers. The northern portions of Iowa, Illinois, Indiana, and Ohio were glaciated and much of the terrain reflects the influence of this glacial process. Glacial deposits vary from sandy outwash materials to silty clay moraines and ground tills.

In general, the average annual temperatures in Region D vary from approximately 7°C (45°F) in the northernmost portions of the region to about 13°C (55°F) in the southern extremities. Maximum temperatures vary from 30-35°C (95-100°F) with average minimum temperatures varying from approximately -18°C (0°F) in southern Kentucky to -32°C (-25°F) in northern Iowa. Precipitation generally increases in a southeasterly direction from an average value of approximately 64 cm (25 in.) in northwestern Iowa to approximately 115 cm in central Kentucky. Frost penetration increases from approximately 46 cm per winter season in central Kentucky to as much as 100 cm in extreme northern Ohio, northern Illinois, and northern Iowa. In general, this region has a rather moist climate with severe winters, except in the southernmost portions where the winters are somewhat milder. The Central Lowland in actuality is a very large plain which is the agricultural heart of the United States for many crops. Elevations vary from 150 to 610 meters above mean sea level. The Interior Low Plateaus in Kentucky and central Tennessee which are included in the region are generally plateaus with elevations less than 305 meters above mean sea level. These areas are generally rolling uplands with only moderate relief.

10 Lines to End of Typing Area

Ozark - Region E

Region E consists of the Ouachita Province and the Ozark Plateaus, in northern Arkansas, eastern Oklahoma, and southern Missouri. Generally, the Ozark Plateaus are rolling upland regions with elevations mostly above 305 meters above mean sea level. The Ouachita Province area resembles the Valley and Ridge Province with altitudes between 150 and 610 meters above mean sea level. The northern portion of this province in the eastern half

For Page Numbering

ADL-054-1279-200M

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

of the Ozark Plateaus is generally underlain by older lower Paleozoic sedimentary bedrock units of marine origin, while the remainder of the region is underlain by upper Paleozoic marine and continental sedimentary rock units. This region has not been glaciated to any significant extent and the surficial deposits generally consist of residual soils developed through weathering of the underlying sedimentary bedrock units in a moist mild climate.

Average annual temperatures in Region E increase from approximately 13°C (55°F) in central Missouri to approximately 18°C (65°F) in central Arkansas. Average maximum temperatures are about 35°C (95°F), while average minimum temperatures decrease from approximately -18°C (0°F) in Oklahoma and northern Arkansas to about -23°C (-10°F) in central Missouri. Average annual precipitation throughout the region varies from approximately 100 cm (40 in.) per year in eastern Oklahoma to approximately 115 cm (45 in.) per year in portions of Arkansas and Missouri along the Mississippi River Valley. Frost penetration varies from approximately 25 cm (10 in.) per winter season in central Arkansas to approximately 38 cm (15 in.) per winter season in central Missouri.

Great Lakes - Region F

Region F includes the Superior Upland Province in northern Wisconsin and far eastern segments of Minnesota, the remainder of Wisconsin which is in the Central Lowland Province and all of Michigan which is also in the Central Lowland Province. These portions of the Central Lowland Province have been divided from the remainder of the province because of significant differences in temperature and precipitation between Wisconsin and Michigan and the states to the south in the Central Lowland Province such as Indiana, Kentucky, and central Tennessee. The Superior Upland portion of the region is a highland region with altitudes up to 610 meters, but without local relief. Drainage is very irregular in this upland region and many lakes are found throughout this area. In actuality, the Superior Upland extends far north into Canada around both sides of Hudson Bay.

10 Lines to End of Typing Area

Average annual temperatures in Region F decrease from approximately 7°C (45°F) in southern Wisconsin to about 2°C (35°F) in eastern Minnesota. Average maximum temperatures increase from approximately 32°C (90°F) in eastern Minnesota to about 35°C (95°F) in southeastern Michigan, while average minimum temperatures increase from approximately -40°C (-40°F) in eastern Minnesota to approximately -23°C (-10°F) in southeastern Michigan. Precipitation decreases from approximately 90 cm (35 in.) per year in southeastern Michigan to approximately 64 cm (25 in.) per year, on the average, in eastern Minnesota. Frost penetration is a major factor in this region, increasing from approximately 76 cm (30 in.) per winter season in southern Michigan to more than 127 cm (50 in.) in eastern Minnesota.

Most of Michigan is underlain by upper Paleozoic formations of Mississippian and Pennsylvanian sedimentary bedrock units, while the southern portion of Wisconsin is underlain by lower Paleozoic formations, including sedimentary marine bedrock units. The Superior Uplands Province is

ADL-054 1279-200M

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8 1/2 x 11

TOP

generally underlain in northern Wisconsin and eastern Minnesota by metamorphosed bedrock units. These bedrock units include materials as old as Precambrian bedrock units (such as the Baraboo quartzite) in northern Wisconsin and portions of eastern Minnesota. Almost all of this region, with the exception of a small portion of Wisconsin, has been glaciated by a number of glacial advances and retreats. Glacial deposits of various types dominate the surface land forms in the region. Surficial soils vary from sandy outwash deposits to extremely fine-grained lacustrine deposits.

Superior - Region G

Region G includes the northern extension of the Central Lowland Province which includes most of Minnesota, the eastern two-thirds of North Dakota, and the eastern half of South Dakota. Most of this region is underlain by Cretaceous sedimentary formations consisting of marine and continental deposits intertongued throughout eastern North Dakota and eastern South Dakota. The exception is the southwestern corner of Minnesota and the eastern border of South Dakota which is a region of metamorphic rocks. Minnesota is much more complex in its geologic framework with lower Paleozoic rock units in southeastern Minnesota consisting of Ordovican and Silurian sedimentary units and Cretaceous sedimentary units in southwestern Minnesota. Both give place to metamorphosed bedrock units throughout much of the remainder of the state. Slightly to the east of the boundary between North Dakota and Minnesota a large area of Quaternary glacial drift is found as a major unit of equal significance with the bedrock units throughout the remainder of Minnesota. In this area, large deposits of lacustrine clays are found as the remnants of glacial lakes. Much of the remainder of Region G is covered with glacial drift, which is generally a vast plain of glacial till broken only locally by morainic ridges of till. In some segments of southeastern Minnesota, thick deposits of wind-placed silt called loess, of glacial origin, are also found.

10 Lines to End of Typing Area

The climate within Region G is generally humid with severe winter conditions. Average annual temperatures range from approximately 2°C (35°F) in northern North Dakota to approximately 7°C (45°F) in southern Minnesota. The average maximum temperature in the region varies from approximately 38°C (100°F) in the Dakotas to approximately 35°C (95°F) in central Minnesota, while the minimum temperature on the average increases from approximately -43°C (-45°F) in northern Minnesota and North Dakota to approximately -29°C (-20°F) in extreme southeastern Minnesota. Average annual precipitation varies from approximately 50 cm (20 in.) per year in the Dakotas to approximately 76 cm (30 in.) per year in southeastern Minnesota. Throughout this region, frost penetration during a winter season increases from an average depth of approximately 100 cm (40 in.) in South Dakota to more than 50 inches during a winter season in northern Minnesota.

For Page Numbering

ADL 054-1279-200M

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

Southern Plains - Region H

Region H includes the southeastern portion of the Central Lowland Province and the southern portion of the Great Plains physiographic province. It includes all portions of Kansas and most of Oklahoma, except for the eastern portion included in the Ouachita Province. Most of Texas is included in this province with the exception of the eastern third, which is included in the Gulf Coastal Plain, and the far western section, which is included in Region K. The eastern third of New Mexico and the portion of Colorado east of Denver are also included in Region H. Average annual temperatures in this region range from approximately 13°C (55°F) in eastern Colorado and Kansas to approximately 18°C (65°F) in central Texas. Average maximum temperatures range from more than 38°C (100°F) in eastern New Mexico and Colorado to approximately 35°C (95°F) in eastern Kansas and Oklahoma, while average minimum temperatures range from approximately -29°C (-20°F) in eastern Colorado to approximately -18°C (0°F) in eastern Oklahoma. Average annual precipitation ranges from approximately 100 cm (40 in.) per year in eastern Kansas and Oklahoma to approximately 38 cm (15 in.) per year in eastern Colorado and New Mexico. Frost penetration in this semi-arid region is generally less than 50 cm (20 in.) per winter season and decreases from about 20 in. per winter season in extreme northern Kansas to about 13 cm (5 in.) per year in New Mexico.

The sub-surface deposits vary from Cretaceous sedimentary deposits throughout central Texas to upper Paleozoic sedimentary rock units in north central Texas, Oklahoma and eastern Kansas to Tertiary sedimentary rock units as well as lake and stream deposits in western Texas, western Oklahoma, and western Kansas. These Tertiary formations interfinger with Cretaceous sedimentary formations throughout much of western Kansas, eastern Colorado, and far eastern New Mexico. Additionally, in New Mexico the geologic conditions are extremely varied in the eastern third of the state, with upper Paleozoic sedimentary rock units intermingled with metamorphic rock units in the mountainous northern portions of this section of New Mexico, as well as Cretaceous volcanic deposits intermingled with sedimentary bedrock units also of Cretaceous age. A very significant deposit of Quaternary materials extends southeastward through eastern New Mexico into Texas in the Tacos River Valley region. Throughout much of Texas and Oklahoma included in this region and portions of eastern New Mexico and eastern Colorado, the surficial deposits are very thin or absent over the bedrock units. Very stony, thin deposits of surficial soils characterize these areas. Throughout much of western and central Kansas, wind-deposited silt materials overlie the bedrock units and are intermingled with wind-deposited sands. These sands are also found in extreme eastern and southeastern New Mexico and extend into those portions of Texas immediately adjacent. Very extensive deposits of recent alluvium are found in the Tacos River Valley, extending southeastward from New Mexico into Texas, and along the Arkansas River Valley, extending from eastern Colorado across Kansas.

10 Lines to End of Typing Area

ADL 054-1279-200M

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8 1/2 x 11

TOP

Northern Plains - Region I

Region I consists of the northern portion of the Great Plains physiographic province. It includes all of Nebraska (the extreme eastern portion of Nebraska, which is in the Central Lowland Province has also been included in this region), the western half of South Dakota, the western half of North Dakota, most of Montana to the northeast of a line running from Sheridan, Wyoming to Great Falls, Montana, and the extreme eastern portion of Wyoming. Most of this region is characterized by the major drainage features of the Missouri River and its tributaries, including the Yellowstone River and the Platte River. The bedrock units vary from upper Paleozoic Permean sedimentary rocks (in extreme southeastern Nebraska) to Cretaceous sedimentary formations (in eastern Nebraska, central South Dakota, and central North Dakota), to Tertiary sedimentary bedrock units and lake and stream deposits (in western Nebraska, western South Dakota, western North Dakota, eastern Wyoming, and eastern Montana). Cretaceous bedrock units are found in central Montana consisting primarily of continental sedimentary rock units and also volcanic rock areas. A large deposit of Quaternary dune sand is found in western Nebraska.

The surficial soils in this region vary from alluvial deposits along the major streams including the Missouri River and its tributaries, to wind-deposited silt in eastern Nebraska, and wind-deposited dune sand in western and central Nebraska. Throughout much of western South Dakota and southwestern North Dakota as well as eastern Wyoming and the major portion of Montana, stony, thin surficial soils are encountered. The northern third of North Dakota and Montana included in this region have been glaciated and the deposits generally include glacial drift in a vast till plain.

The climate in this region is somewhat dry. Average annual temperatures vary from approximately 4°C (40°F) in northern Montana to approximately 10°C (50°F) in southern Nebraska. Average maximum temperatures are generally on the order of 38°C (100°F), while average minimum temperatures range from approximately -29°C (-20°F) in southern Nebraska to about -40°C (-40°F) in northern Montana. Frost penetration during a winter season averages generally from approximately 50 cm (20 in.) in southern Nebraska to more than 100 cm (40 in.) in northern Montana and North Dakota. Average annual precipitation varies from approximately 76 cm (30 in.) per year in the extreme southeastern portion of Nebraska to about 38 cm (15 in.) per year in central Montana. This northern portion of the Great Plains Province is actually the western extension of the Central Lowland, with elevations rising to the westward from approximately 610 meters (2000 ft) above mean sea level to about 1525 meters (5000 ft) above mean sea level in the western portions of the region.

10 Lines to End of Typing Area

Rocky Mountains - Region J

Region J includes the Northern Rocky Mountains physiographic province, the Middle Rocky Mountains physiographic province, the Wyoming Basin Province, the Southern Rocky Mountains, and the Colorado Plateau Province. This region extends from the Canadian border south to central Arizona.

ADL-054 1279 200M

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8 1/2 x 11

TOP

It includes northern Arizona, northwestern New Mexico, western Colorado, most of Utah to the east of Provo, all of Wyoming not included in Region I, the remainder of Montana not included in Region I, most of Idaho, and the far northeastern corner of Washington. The Northern Rocky Mountains Province includes linear blocky mountains and basins in the eastern portion of the province and highly irregular granitic mountains, without identifiable linear trends, in the southwestern portion of the province in Idaho. In this region, altitudes generally lie between 1220 to 2100 meters (4000 and 7000 ft) above mean sea level. In the Middle Rocky Mountains in northwestern Wyoming there is generally an irregular assortment of different mountain types with differing trends in topography and geologic materials interspersed with semi-arid intermountain basins. Altitudes in this region generally range from 1500 to 3700 meters above mean sea level. The Wyoming Basin Province consists generally of an elevated semi-arid basin, with some isolated lower mountains, although altitudes lie mostly between 1500 to 2100 meters above mean sea level. The Southern Rocky Mountains Province contains a series of intermountain basins and mountain ranges trending generally north and south. This is the highest part of the Continental Divide in the United States, with altitudes ranging generally from 1500 to 4300 meters above mean sea level. The Colorado Plateau, the southernmost extension of Region J, contains the highest plateaus in the United States. The land surface is generally above 1500 meters above mean sea level and elevations extend up to 3400 meters above mean sea level. This semi-arid region is the major canyon land of the United States. The bedrock geology in this province is extremely varied. It includes extensive areas of metamorphic rock units in the Rocky Mountain region, particularly the Northern Rocky Mountains, large granitic batholiths of late Mesozoic and early Cenozoic age in southern and central Idaho, and extensive deposits of volcanic bedrock in southern Idaho, northwestern Wyoming, the Southern Rocky Mountains in western and central Colorado, and the southern and western portions of the Colorado Plateaus. The Southern Rocky Mountain area also contains large exposures of metamorphosed bedrock units of varying ages. In the Colorado Plateau area the bedrock units range from Paleozoic sedimentary rock units to early Mesozoic formations of Triassic and Jurassic canyon-forming sandstones in northern Arizona, northwestern New Mexico, and southern Colorado. Sedimentary bedrock units are found throughout central and eastern Utah, northwestern Colorado, and southwestern Wyoming. These sedimentary formations generally consist of continental sedimentary bedrock units but also include lake and stream deposits and some volcanic materials. In addition to these units, Quaternary gravel fans and alluvial deposits are found in western Utah.

10 Lines to End of Typing Area

Climatic conditions in Region J are extremely variable because of the extreme differences in elevation. The climate varies from semi-arid to a mountain climate, with average annual temperatures varying to a great degree with altitude from 10°C (50°F) to approximately 2°C (35°F) at higher altitudes. Maximum temperatures, on the average, range from 38°C (100°F) to less than 27°C (80°F), again greatly influenced by local elevations. Average minimum temperatures generally range from approximately -18°C (0°F) in Arizona to lower than -29°C (-20°F) in northern Idaho.

For Page Numbering

ADL 064 1279-2002

Average annual precipitation is generally on the order of 25 cm (10 in.) per year, although precipitation varies significantly with topographic features. Frost penetration is also extremely variable because of the climatic variations associated with the extreme differences in elevation.

Surficial deposits in Region J vary from glacial drift consisting of a till plain and morainic ridges in extreme northern Idaho, northwestern Montana, northeastern Washington to stony, very thin surficial soil deposits as well as local thin mountain soils with glacial influences throughout most of Wyoming, Idaho, and Montana. In southwestern Wyoming and much of Arizona, sandy desert and semi-desert surficial deposits are found consisting of essentially loose sand areas between bedrock exposures. Local exposures of alluvium are found along major streams and in alluvial fans. In portions of central and western Utah, very extensive exposures of lake bed clays of glacial age are also found. In western New Mexico, sandy desert soils, local alluvial deposits, bare stony desert soils, valley fill between mountains (consisting largely of gravel), sands in fans at the base of mountains, and dry lake bed deposits are found. Bedrock geology conditions are very complex and irregular and surficial deposits reflect this irregularity.

Great Basin - Region K

Region K consists basically of the Basin and Range physiographic province which extends from western Texas in a belt through southwestern New Mexico, southern Arizona, southeastern California, and northward into Nevada and western Utah, as far north as southern Oregon. This Basin and Range Province consists mostly of blocky, elongated mountains separated by arid desert basins. The geologic structure generally produces topographic features which trend north and south. This pattern is more irregular in the southern portions of the region. Altitudes range from below sea level in southeastern portions of California to altitudes of more than 3700 meters above mean sea level, but relief between the basins and the neighboring mountains is generally less than about 1500 meters. Many of the basins in Nevada, southern Oregon and western Utah are closed basins without exterior drainage. The bedrock units in this region vary from Quaternary lake beds, playa deposits, alluvium, and gravel fans to volcanic rock units, metamorphic rock units in central Arizona, sedimentary Paleozoic formations in the mountain ranges, particularly in Nevada, and volcanic bedrock units in northern Nevada and southern Oregon. The bedrock geology in the region is extremely complex reflecting the orogenic processes that have operated in this region. The surficial deposits in the region vary from glacial-age lake beds in northwestern Nevada to valley fill deposits between the mountains in the Basin and Range area consisting largely of gravel and sand alluvial fans at the foot of the mountains grading into silty, clayey, dry lake beds or alluvial bottoms in the valleys. Much of the area has only a thin surficial coating of stony desert soils created through the arid climatic influence on weathering of the exposed rock units.

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

The climate in Region K varies from arid to semi-arid with average annual temperatures generally in the range of 16 to 21°C (60 to 70°F) in southern New Mexico and Arizona to approximately 10°C (50°F) in central Nevada and western Utah. Average maximum temperatures exceed 43°C (110°F) in central Arizona and southeastern California, while average minimum temperatures are rarely lower than -15°C (5°F) in southern Arizona and southeastern California. In the more northerly portions of the region (in northern Nevada and northwestern Utah) maximum temperatures on the average are approximately 38°C (100°F) and minimum temperatures generally average -26°C (-15°F). In general, throughout the region, average annual precipitation rarely exceeds 25 cm (10 in.) per year. Frost penetration is not a major consideration because of the arid conditions.

Columbia Plateau - Region L

Region L consists of the Columbia Plateau physiographic province. The Columbia Plateau consists mostly of a plateau of lava flows. Elevations generally are below 1500 meters above mean sea level. This is generally a semi-arid plateau but is crossed by two major river systems, the Columbia River and the Snake River. The bedrock units in the region consist almost entirely of volcanic bedrock units of Cenozoic age, although some Paleozoic rock units are exposed in the southwestern portion of the plateau in the Snake River drainage area and some Tertiary deposits of sedimentary bedrock units as well as lake and stream deposits exist along the Columbia River drainage in the plateau region. The surficial soils in the region generally are very thin, except along major streams where significant deposits of stream alluvium may be found and in the Palouse region in Washington where a very thick deposit of glacial age loess is found.

This is a region with a semi-arid to mountain climate characterized by average annual temperatures between 7 and 10°C (45 and 50°F), with maximum temperatures on the average of approximately 38°C (100°F) and average minimum temperatures of approximately -23°C (-10°F). Average annual precipitation is extremely variable with elevation in the region, varying from approximately 25 cm (10 in.) per year in southwestern Oregon to as much as 100 cm (40 in.) per year in central Washington. Average frost penetration in the region is extremely variable depending upon elevation. This is a region characterized by very complex geologic conditions in that very extensive deposits of volcanic bedrock units exist in the region and these units have undergone varied amounts of weathering before being covered with more recent volcanic deposits or unconsolidated deposits of even younger age.

10 Lines to End of Typing Area

Pacific Coastal - Region M

Region M includes the Cascade-Sierra Nevada Province in central California and the Pacific Border Province, both of which extend northward through California into Oregon and Washington to the Canadian border. The Cascade-Sierra Nevada Province consists of northerly trending mountain ranges. The Cascade Range consists primarily of a series of volcanic mountains, while the Sierra Nevada Mountains consist primarily of blocky masses of granite with a long, gentle western slope and an abrupt, steep eastern

For Page Numbering

ADL 054-1279-200M

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

slope. Elevations in the Cascade-Sierra Nevada Province may exceed 4300 meters above mean sea level. In general, precipitation is concentrated on the western slopes of the mountains and the eastern slopes are semiarid. In the Pacific Border Province, the coastal ranges generally have altitudes below 610 meters above mean sea level and are separated from the higher Cascade-Sierra Nevada ranges by valleys and troughs where surface elevations generally are approximately 150 meters or less above mean sea level. The bedrock units in this region vary from granite batholiths of late Mesoizoic and early Cenozoic age in the Cascade-Sierra Nevada region (primarily in the Sierra Nevadas) to volcanic rocks of Cenozoic age in the Cascade Ranges, with Quaternary valley fill deposits along the San Joaquin and Sacramento River Valleys in central California. To the west of the Quaternary valley fill, deposits are found of sedimentary Cretaceous bedrock units in the Pacific Border Province, Tertiary volcanic formations along the Washington and Oregon coast, and sedimentary marine Tertiary bedrocks along the coastline from central California southward to the Mexican border. Between San Francisco and the Oregon border approximately, the bedrock units along the California coastline consist of Triassic and Jurassic marine and some metamorphic rock units. This mountainous region obviously displays complex geologic characteristics. In the Sierra Nevada area, the surficial soil deposits are extremely thin, if not absent, and they represent inplace weathering of the bedrock units in the mountains. In the central California Valley, thick deposits of alluvium are found. In the California coastline area from San Francisco south, the surface deposits are sandy and stony and generally are thin over the bedrock units, with the exception of areas around estuaries and principal stream valleys where alluvial materials may occur in significant thickness. North of San Francisco extending up to and immediately north of the Oregon border, the bedrock units have weathered into deep deposits of residual clayey soils. Northward along the Oregon and Washington coast, the surficial deposits consist of deep clayey residual soils formed through weathering in a moist climate of the volcanic rock units found in that area. In some portions of Oregon, volcanic ash deposits are found in association with the volcanic mountains of the Cascade Range. In northwestern Washington, in the area around Seattle, some glacial drift deposits also are to be found. The southern portion of this region has a semi-arid climate, while the region generally to the north of San Francisco has a rainy climate with mild winter weather. Average annual temperatures range from approximately 21°C (70°F) in southern California to approximately 7°C (45°F) in extreme northwestern Washington. Maximum temperatures range from approximately 43°C (110°F) in extreme southern California to approximately 27°C (80°F) in northwestern Washington, while average minimum temperatures throughout the region rarely are lower than -18°C (0°F). Average annual precipitation is generally between 25 and 50 cm (10 and 20 in.) per year in southern California, but this value increases drastically north of San Francisco and some portions of the Pacific Northwest receive more than 100 inches of average annual precipitation. Frost penetration is not a significant factor throughout this region.

10 Lines to End of Typing Area

For Page Numbering

ADL-054-1279-200M

EXHIBIT D

PLANT-BY-PLANT PRESENTATION OF OTHER SITE SELECTION INFORMATION

The following summaries reflect the information that was available to the investigators in mid-1980.

A brief description of the plants with some pertinent information is presented in Exhibit D.

Region A-1, Gulf Coastal Plain

Barry, Alabama Power

The Barry plant is in an area where, because of saline intrusions, there is a significant potential for groundwater overdraft, even though there are more than 160 cm (64 in.) of precipitation per year. The unlined pond is seven years old and underlain by five to six meters of silty clay. The reported pond influent includes 19% miscellaneous inputs. There were data on at least 10 priority pollutants.

Greene, Alabama Power

The Greene plant is not within the reported area of groundwater overdraft. It is similar to Barry in that it is 15 years old and its combined pond is underlain by about seven meters of clay silt. Thirty-nine percent of the pond influent is building sump and demineralizer water. Water balance and priority pollutant data were unavailable.

Tombigbee, Alabama Electric Coop.

The Tombigbee plant area has a combination of previous coastal soils and excessive precipitation. Data were available on bottom ash and fly ash discharge water balance. There were no other site-specific data available.

Big Bend, Tampa Electric

The Big Bend plant is in a region of coarse coastal soils with excessive precipitation. There were reported data on at least 10 priority pollutants as well as information on bottom ash discharge in the water balance. However, there were no data on the waste type and disposal method at the plant.

Crist, Gulf Power

The Crist plant is in an area of coarse coastal soils with excessive precipitation. One complicating factor at this plant is that 63% of the pond influent is from floor drains and cooling tower blowdown. There were water balance discharge data on fly and bottom ash.

Smith, Gulf Power

The area containing the Smith plant has coarse coastal soils and excessive precipitation. The 14-year-old unlined pond is underlain by sandy silty soils. The pond influents are reportedly 99% coal ash, but there was an absence of water balance or priority pollutant data.

Mitchell and Wansley, Georgia Power

The two Georgia Power plants (Mitchell and Wansley) are both located in areas with excessive precipitation, and Mitchell is in the region of pervious coastal soils. Data on the type of soil underlying each disposal pond were not available. Water effluents are reportedly recycled. The Mitchell plant has 40% low-volume wastewater in the pond influent and information was available on both fly and bottom ash discharge water balance and nine priority pollutants.

Joppa, Electric Energy

The Joppa plant, located in Massac County, Illinois, is not in an area of coastal soil and does not receive excessive precipitation. There was no information available on disposal method or waste type. There was water balance information on the bottom ash and fly ash discharge as well as information on eight priority pollutants.

Shawnee, Tennessee Valley Authority

The Shawnee plant is also not located on coastal soils, although it does experience excessive precipitation. The known history of the adjacent ponds where various combinations of fly and bottom ash and experimental FGD materials have been disposed is a major complicating factor. The water table is above the bottom of the pond. There were data on the water balance for bottom ash, fly ash, and coal-pile runoff as well as on at least 10 priority pollutants. Pond effluent is reportedly recycled.

R. D. Morrow, Southern Mississippi Electric

This plant is in an area of excessive precipitation. Lime is added to the fly ash FGD as a pretreatment process. The landfill is only about one year old and is reported to be underlain by a natural clay liner. Although there are three wells at the fill, there was no monitoring data reported to be available. This site is rejected for other reasons discussed in Section 3.2.2.

New Madrid, Associated Electric Coop

The New Madrid plant is not located on coastal soils nor does it receive excessive amounts of precipitation. There was no information available on the waste type or disposal method at this plant. There were data on the water balance for bottom ash and fly ash discharge as well as on seven priority pollutants.

Allen, Tennessee Valley Authority

The water table is reportedly above the bottom of the pond. There is excessive precipitation at this site but it is not located on coastal soils. The Allen plant is at the edge of the region where the Second National Water Assessment identified potential for significant groundwater overdraft. Data were available on the water balance from bottom ash and fly ash discharge and on 10 priority pollutants. There are reportedly miscellaneous influents to the ash ponds.

Johnsonville, Tennessee Valley Authority

The combined fly and bottom ash pond is 11 years old and surrounded by the river (lake) on three sides, with the water table above the bottom of the pond. There is excessive precipitation at this location. An adjacent industrial facility discharges and ponds various chemical wastes in direct proximity to the utility ash pond. Water balance and priority pollutant data are available.

Big Brown, Texas Power & Light

The Big Brown plant is located in an area of generally pervious soils that does not experience excessive precipitation. Surface water utilization is reported to be critical in this general region. The fly ash from this plant is disposed alone in an eight-year-old landfill that is underlain by an unreported amount of clay and has no miscellaneous influents. The bottom ash from the plant is disposed in a seven-year-old pond that is also underlain by clay, reportedly in a layer one-foot thick. Miscellaneous influents are reportedly largely absent and the effluent from the pond is reportedly recycled.

Deeley, San Antonio Public Service Board

This plant does not receive excessive precipitation and it is located in an area of variable soils. The fly ash landfill reportedly has no other influents, is lined with two parts clay and one part PVC. The fill is two and one-half years old and is underlain by 11 meters of sand and clay. There are four monitoring wells around the fill, and background data were reportedly available.

The bottom ash pond effluent is reportedly recycled. The pond is two and one-half years old and receives 100% bottom ash.

Martin Lake, Texas Power & Light

This plant is located in an area of variable soils, that does receive excessive precipitation. The unlined landfill in a mine is three years old and underlain by silt and clay for up to 4 to 10 meters. FGD sludge and bottom ash are added to the fill after interim ponding, a potential complicating factor.

The bottom ash and FGD interim pond is four years old, and underlain with at least one foot of clay. Effluent from the pond is recycled. The pond is 90% bottom ash and 0 to 10% FGD, therefore, apparently free from other miscellaneous influents.

Monticello, Texas Power & Light

This plant is similar in many ways to the utility's Martin Lake plant discussed above. It does receive somewhat less rainfall and failed to meet the $\geq$ 120-cm criterion. Fly ash from this plant is disposed in a four-year-old, unlined landfill that is underlain by a layer of clay of unspecified depth.

Bottom ash and FGD sludge from the Monticello plant are apparently disposed in interim ponds underlain by clay. The four-year-old bottom ash pond is reportedly underlain by one foot of clay, and its effluent is recycled. This pond reportedly receives 99% bottom ash.

FGD waste from the Monticello site is first disposed in an interim pond that is about two years old. Interim ponding of these wastes precedes the final landfill step, potentially complicating the monitoring of the landfill.

Welsh, Southwestern Electric Power

The Welsh plant is located in the same county as Monticello. The fly ash from the Welsh plant is deposited dry in an unlined landfill that is three years old and is underlain by natural clay soil of unspecified depth.

Bottom ash from the Welsh plant is first disposed in an interim unlined pond which is three years old and underlain by an unspecified thickness of natural clay soil. Twenty percent of the influent is low-volume wastewater. Effluent from the pond is recycled, but to the cooling pond. Final disposal occurs with the fly ash in the combined landfill, again leading to the complication of a two-step disposal (for the fill).

Region A-2, Piedmont and Coastal Plains

Harlee Branch, Georgia Power Co.

The Harlee Branch plant has an inland Piedmont location, relatively good available baseline data (water balance, known priority pollutants), and it may serve as a "best case" environmental impact example of coal ash disposal by ponding in the Piedmont region. It is in an area of high yearly precipitation. In addition to the setting and the apparent relative absence of coal-pile runoff, the Harlee Branch disposal pond appears to receive equal volumes of bottom ash and fly ash influent. This may be a reporting artifact but, if true, might suggest somewhat less impact potential than for the majority of plants in the region for which fly ash/bottom ash influent ratios appear to be generally in the range of 2:5-3:1. The contribution of other wastes to the pond influents, quantified by volume only, is quite high (30%).

Yates and McDonough, Georgia Power Co.

Based on available information, Yates and McDonough appear to be essentially similar, in terms of attractiveness as study sites, to the Harlee Branch plant.

Allen Plant, Duke Power Co.

This site has a number of advantages over other sites in the Piedmont region. The practice of co-disposal of bottom ash and fly ash in unlined ponds, complicated by significant contributions to pond influents from coal-pile runoff and other wastes, is typical of this region. At this site, however, special studies are available on the quality of ash pond influents in addition to water balance data. Baseline data exist for many priority pollutants. Further, more than 20 groundwater monitoring wells exist on this site, and sampling data exist for these as well. The disposal site is adjacent to a river, and the location is essentially typical of the Piedmont region. The age and substrate combination also appears favorable.

Other Duke Power Co. Plants

The other Duke Power Co. plants that were included for consideration in the Piedmont region (Belews Creek, Buck, Cliffside, Dan River, Marshall, River Bend, and Lee) also reportedly have combined disposal ponds adjacent to surface waters. Co-disposal of fly ash and bottom ash, with significant contributing influents from other waste sources including coal-pile runoff, is common to all of these sites. However, information supplied by the utility indicates that the special studies of the ash pond influents and the groundwater monitoring wells that exist for the Allen plant do not exist or are far less extensive for the other Duke Power facilities.

Sutton Plant, Carolina Power & Light

This plant is in the Coastal Plain and has the study advantage of a coastal location with sandy soils and high precipitation, relatively good baseline data, and a mixture of disposal streams very typical for the region. Water balance data are available and suggest regionally typical amounts and ratios of fly ash sluice/bottom ash sluice/coal-pile runoff/boiler cleaning waste. Iron, copper, and pH are monitored in addition to the standard TSS and oil and grease measurements. The area was also reported to experience groundwater supply problems in the Second National Water Assessment (21).

Robinson Plant, Carolina Power & Light

Robinson, like Sutton, appears to represent a coastal plant with typical disposal practices and relatively good baseline data. The same data availability considerations listed for the Sutton plant apply to Robinson. Robinson reports annual average precipitation of less than 120 cm (48 in.).

Lee Plant, Carolina Power & Light

Lee, like Sutton, appears to represent a coastal plant in an area of high precipitation, with typical disposal practices and relatively good baseline data.

Cape Fear, Carolina Power & Light

This recently constructed plant is located on the border between the Piedmont and Coastal Plain sections of Region A2. As is true for other Carolina Power & Light plants, baseline data appears to be relatively good, and there still remain unanswered questions concerning the specifics of disposal practices and environmental circumstances.

Roxboro Plant, Carolina Power & Light

Roxboro is not in the Coastal Plain. Otherwise, the descriptions given for the other Carolina Power & Light plants apply to Roxboro.

Winyah Plant, South Carolina Public Service Authority

This plant may represent a presently atypical but potentially significant disposal practice in the environmentally sensitive coastal area. Information on this plant was very limited in the VERSAR report(1) and the 308 letter submittals. However, it is believed to represent the only instance of 100% FGD waste disposal in an unlined pond in the A2 Region. More importantly, it is located in the Coastal Plain, in an area of high precipitation. Unresolved questions include specifics of the disposal practice and site environment, and extent and availability of baseline data.

Bremo Bluff, Virginia Electric & Power

The absence of environmental extremes, plus the apparently very high (70%) waste pond contributions from miscellaneous sources make Bremo Bluff a relatively less attractive study site. In addition, the disposal pond is only two years old, so that leachate permeation of the underlying silt is less than likely.

Indian River, Delmarva Power & Light

This plant is located in the coastal area. The old pond will soon be phased out in favor of landfilling these wastes, a potential complicating factor. Water balance data were available but may be irrelevant to the landfill operation.

Dickerson, Potomac Electric Power

Dickerson is located near, but not necessarily in, the Coastal Plain, where a large variety of soil types are possible. A potential complicating factor is that scrubbed fly ash and bottom ash are interim ponded in one of four on-site ponds, apparently located in series. The available information on the ponds was qualitative in nature (the ponds evidently contain mostly fly ash), and there were no available water balance data or monitoring data for either disposal site.

Titus, Metropolitan Edison

Titus is also located in an area where a variety of soil types exist. The unlined landfill is 30 years old, over a clay/shale substrate. Three wells, at varying depth, exist at the fill, and chemical analysis data were reported available. Landfill composition data were also available.

Potomac River, Potomac Electric Power

The Potomac River plant employs one of the relevant control technologies, dry disposal. However, it appeared to meet none of the regional/generic criteria, and site-specific information was largely unavailable.

Plants with Insufficient Information

Insufficient information was available to evaluate fully the plants listed below. Specifically, the lack of information on disposal practices represented a serious constraint, favoring elimination of these sites regardless of their rating.

- Canadys, South Carolina Electric & Gas
- Jefferies, South Carolina Public Service Authority

- McMeekin, South Carolina Electric & Gas
- Urquhart, South Carolina Electric & Gas
- Wateree, South Carolina Electric & Gas
- Eddystone, Philadelphia Electric

Region B - Appalachian

Alabama Power Plants

The Gaston and Gorgas facilities are both located in an area that receives greater than 120 cm (48 in.) of precipitation per year. Ponds at both plants reportedly receive greater than 20% miscellaneous influents, including cooling tower blowdown. The Gaston facility had data available on priority pollutants and on the volume of bottom ash discharge. The water table is reportedly high at Gaston where the 19-year-old fill is underlain by up to 10 meters (33 feet) of sandy clay.

Widows Creek, Tennessee Valley Authority

This plant is located in an area that receives greater than 120 cm (48 in.) of precipitation per year. The FGD and combined ash disposal ponds are located over a reclaimed swamp. There was chemical information available from monitoring wells, as well as information on bottom ash and fly ash water balance and priority pollutants. The effluent is recycled, but to the plant intake area. Aquatic biota in the ash pond provide a potential study opportunity, as does the proximity of both the ash and FGD ponds to the small Widows Creek.

Georgia Power Plants

The Bowen and Hammond facilities both receive greater than 120 cm (48 in.) of precipitation per year. For both facilities, information was available on water balance (volume of bottom ash and fly ash discharge) and on known priority pollutants. Both facilities reportedly recycle pond effluents and experience the potential complicating factor of receiving greater than 20% miscellaneous influent.

Big Sandy, Kentucky Power

This facility is located in an area that received no credit for generic environmental factors. Fly ash and some bottom ash are disposed of in an 11-year-old unlined pond underlain by five meters of silty clay and a high water table. This pond receives runoff from the bottom ash landfill. There was information available on bottom and fly ash water volumes and known priority pollutants. Bottom ash is first disposed of in an unlined pond where water is reportedly recycled. The bottom ash is then landfilled.

Asheville, Carolina Power and Light

This facility is located in an area where about 120 cm (48 in.) of precipitation per year occurs. Information was available on the volume of bottom ash and fly ash water balance.

Cleveland Electric Illuminating Plants

The four Cleveland Electric Illuminating facilities (Ashtabula, Avon Lake, East Lake, and Lake Shore) are all located in areas that do not experience extremes in temperature or precipitation.

The Ashtabula facility provided influent data for the composition of its landfill, which was considered a positive characteristic. It was reported that a new bottom ash pond will be built in 1980, which is a potential complicating factor. The bottom ash pond presently receives 100% bottom ash, but this interim step potentially complicates evaluation of the final bottom ash landfill.

The fly ash landfill setting at the Avon Lake facility is 12 years old and is underlain by six meters (20 feet) of clay. The composition of the landfill was reported and priority pollutant data was available. The bottom ash pond at this facility is expected to be new in 1980, which is a complicating factor. The fact that the landfill receives bottom ash that has already been ponded is a complicating factor for the landfill.

The East Lake facility has an ash landfill that is only one and one-half years old and is underlain by one and one-half to two meters (five to seven feet) of silty clay. The composition of the fill was reported. There is a potential land use issue at this site since there are plans to use the area for recreation (a track and a football field) when it is no longer used as a landfill. A complicating factor for the bottom ash disposal operation is the fact that a new pond is planned for 1980. The old pond received 100% bottom ash, a positive characteristic. There was information available on water balance for fly ash from the plant and on known priority pollutants.

At least one of the ash landfill sites for the Lake Shore facility receives 95% miscellaneous waste. There are two wells at one site, from which monitoring data were available. The ten-year-old fill is reportedly over 11 meters (36 feet) of shale, above the water table. The fills receive bottom ash that has already been ponded. A new bottom ash pond is expected to be built in 1980 which again complicates this facility. The old pond received 100% bottom ash.

Ohio Edison Plants

The three Ohio Edison facilities (Burger, Niles, and Sammis) are all located in a region that does not generally experience extremes in temperatures or precipitation. Only the Niles plant is located in an area that has less than 150 frost-free days per year.

The water table at Burger is reportedly five meters (16 feet) below the pond surface, and the ponds were 23 years old. Information was available on the fly and bottom ash water balance and on known priority pollutants. No data were available for the off-site landfills.

The Niles facility disposes of fly ash in a pond that is only about one year old. A complicating factor is that the fly and bottom ash ponds reportedly are connected at this facility. There was information available on the water balance of fly and bottom ash and on known priority pollutants. The bottom ash pond received 100% bottom ash and is more than 25 years old over a high water table (~5 m). It appears that although each pond is indicated to receive 100% bottom ash or fly ash it may function as one large pond.

A complicating factor at the Sammis facility is that the combined fly and bottom ash pond reportedly has an underground spring below it. Attempts to plug the spring have been unsuccessful. There is information on bottom ash discharge volume and on known priority pollutants. No data were available on the off-site landfill for the ash from this facility.

Cardinal, Cardinal Operating

This facility is located in a region that does not experience extremes in temperature or precipitation, and there are greater than 150 frost-free days per year. The fly ash at this facility is disposed of in a 12-year-old pond that is surrounded by a layer of three to five meters (10 to 16 feet) of silty clay and the water table. It appeared from a photograph that the fly ash pond is located very close to a river. The pond reportedly receives 100% fly ash. The bottom ash pond also was credited for its age/substrate combination. It is 13 years old and is reportedly underlain by eight to ten meters (26 to 33 feet) of silty clay over gravel, with the water table at three to five meters. An additional complicating factor is the fact that this pond receives 42% of "other wastewater." Effluent from the pond is recycled.

Conesville, Columbus and Southern Ohio Electric

This facility is located in an area that does not experience extremes in temperature or precipitation. Fly ash, some bottom ash, and stabilized FGD waste (IUCS process) are disposed of in a three-year-old landfill that is reportedly underlain by five meters of FGD waste, then five meters of silty bottom ash, then one meter of sand and silt. This combination of wastes was seen as a complicating factor in an otherwise favorable setting. There are monitoring wells at the fill and recorded data. The majority of the bottom ash at this facility is disposed of in an adjoining 23-year-old pond that is underlain by soil and ash for six to eight meters (20 to 25 feet). The water table is at a depth of about two meters. This is seen as a positive setting characteristic because of the potential for monitoring groundwater contamination. There are monitoring wells for the bottom ash pond and data are available from the on-going program sponsored by EPRI. Both ponds are relatively close to the Muskingum River. There is also information on water balance and known priority pollutants.

USE THIS SHEET FOR REPORT TYPING 8-1/2 x 11

TOP

Gavin, Ohio Electric

One hundred percent fly ash at this facility is disposed of in a six-year-old unlined pond over unspecified substrate, and a water table at least eight meters down. The bottom ash is disposed of in a six-year-old pond that is underlain by brown clay for five meters and then relatively impervious clay shale for 1.5 meters, over a water table at least six to eight meters (20 to 25 feet) below the surface. This was considered a negative characteristic. A complicating factor for the bottom ash pond is the fact that it reportedly receives 76% cooling tower blowdown and wastewater. There was information on bottom and fly ash water balance and on known priority pollutants. Effluent from the bottom ash pond is reportedly recycled.

Kyger Creek, Ohio Valley Electric Co-op

This facility is located in a region that does not experience extremes in temperature or precipitation. The fly ash and bottom ash ponds at this facility are about 25 years old, over silty clay, with the water table reportedly at eight meters. There was information on water balance and known priority pollutants for the plant. The two bottom ash ponds reportedly receive 100% bottom ash, a positive characteristic.

Muskingum, Ohio Power

This facility is also in an area not credited for extremes in temperature or precipitation. One hundred percent fly ash is disposed of in a five-year-old unlined pond that is close to a river, and underlain by silty clay and the water table at about three meters. Bottom ash is disposed of in two different unlined ponds with about 30 to 70% miscellaneous influents, also close to the river. One pond is 28 years old, the other 12, and both are in the same type of setting as the fly ash pond. There was information available on bottom ash and fly ash discharge volumes as well as known priority pollutants.

10 Lines to End of Typing Area

Poston, Columbus and Southern Ohio Electric

This facility is in an area that does not experience extremes in temperature or precipitation. Combined fly and bottom ash are disposed of in an unlined pond over 30 years old, over a silty clay and sandy/shale substrate. There was information available on the volume of bottom ash and fly ash water balance, and pond effluent was reportedly recycled. Fly ash is also apparently landfilled off-site, but no information was available on that operation.

Bruce Mansfield, Pennsylvania Power

This facility is also in an area that has less than 150 frost-free days per year. Stabilized FGD sludge is piped four kilometers (seven miles) to a very large disposal pond (566 ha, 1400 acres) near the Ohio River. Data from monitoring wells were available. The disposal area is proximate to a small stream, but has a point source discharge to it, reducing the opportunity to study discrete non-point source impacts.

ADL-054-1279-200M

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8 1/2 x 11

TOP

Brunner Island, Pennsylvania Power & Light

Combined fly and bottom ash are deposited in a nine-year-old unlined pond, over a one and one-half to five meter deep water table in alluvium. There were data available on the fly and bottom ash water balance and on known priority pollutants. The facility is located in an area that received no credit for generic climatic or water use factors.

Cheswick, Duquesne Light

Most of the climatic and environmental conditions in the area of this site are not extreme, but the number of frost-free days is less than 150. Fly ash is directly disposed of in a mine. In the recent past, this fly ash has been sluiced to the landfill, although it is expected that it will be trucked from a dry silo when construction of this storage facility is completed in 1980. Monitoring wells with data reportedly exist in the vicinity of the landfill.

Conemaugh, Pennsylvania Electric

The regional environmental characteristics of this facility are similar to those described above for the Cheswick facility. As with Cheswick, fly ash is placed directly in a nine-year-old, unlined landfill, with four meters of silty clay between the fill and the water table. Bottom ash and coal refuse, the latter in significant quantities, are also disposed of in this fill, a complicating factor. One monitoring well exists with data on a relatively limited group of physical and chemical parameters. Water balance information is available for the interim pond which is only three years old, underlain by four meters (13 feet) of silty sand above the water table.

Elrama, Duquesne Light

10 Lines to End of Typing Area

The climatic/environmental factors for this facility are the same as for the preceding ones. Fly ash and bottom ash are co-disposed of in an unlined interim pond containing various amounts of influents including fly ash, bottom ash, FGD wastes, and miscellaneous wastes. Water balance data are available for this facility and monitoring wells are in existence in the vicinity of the pond with data on some metals and other inorganic constituents. An abandoned strip mine (located near the Youghiogheny River) is being utilized for disposal of stabilized FGD wastes, and some coal ash. Runoff and leachate water quality are monitored on a quarterly basis at this landfill site.

Homer City, Pennsylvania Electric

The area of this site has the same characteristics as described above for Cheswick, Conemaugh, and Elrama. Fly ash is placed directly in an unlined landfill, 12 years old and underlain by two meters of silty and sandy clay, and then the water table. This landfill receives fly ash, bottom ash, and a small amount of clarifier sludge (2%). Data from two monitoring

For Page Numbering

ADL 054 1279 200M

wells exist, mostly for major dissolved solids (iron is the only heavy metal). Bottom ash is placed in an unlined, 100% bottom ash interim pond of unspecified age. Data were reportedly not available from the one existing monitoring well, and the pond effluent is recycled.

Keystone, Pennsylvania Electric

Climatic conditions at this facility are very similar to those described for the previous four plants. This 14-year-old landfill overlies 10 meters (33 feet) of silty clay, with the water table at 8 to 19 meters (26 to 62 feet). Two monitoring wells exist and data are available. The interim bottom ash pond also receives a small amount of fly ash (5%) and coal-pile runoff (5%). Although some water balance data are available, data on the age and substrate beneath the pond were unavailable.

10

Montour Plant, Pennsylvania Power and Light

With the exception of relatively high rainfall (120 cm per year), the Montour Plant is in a region very similar to that described for other plants in this region. The unlined pond receives fly ash and bottom ash and about 15% "other wastes." The pond is eight years old and the natural substrate consists of silt loam of unspecified thickness, over bedrock. Water balance data were available and some sampling has been done for priority pollutants.

Phillips, Duquesne Light

Except for experiencing less than 150 frost-free days, the Phillips plant does not experience environmental extremes. Previously (1973-74) the landfill area reportedly received only ash, then unstabilized FGD sludge (1973-74) and some FGD sludge stabilized by the Dravo process. This waste mixture is a potential complication, as is the plan for a new fill to be operational in 1980. The 35-year-old ash pond receiving combined fly and bottom ash is underlain by about three and one-half meters of sandy gravel and about four meters of sand and clay, with the water table reportedly at about 25 meters (80 feet). Water balance data and chemical analyses from two monitoring wells exist for the ash pond. The nine-year-old landfill overlies about five meters of silty clay above the water table. Data were available from two monitoring wells near the fill.

Portland, Metropolitan Edison

This facility is located in eastern Pennsylvania, an area of relatively moderate climatic/environmental conditions. The eight-year-old landfill, whose composition was entirely fly and bottom ash, is located in a slate quarry so that it is perched above the water table as well as being lined with slate. One monitoring well was reported, with chemical analysis data available.

Seward, Pennsylvania Electric

This plant is located in an area of less than 150 frost-free days. The 27-year-old pond (receiving fly and bottom ash) receives other influents which may possibly include mining runoff. The nine-year-old landfill has a clay-to-silty-sand substrate and its runoff is ponded.

Shawville, Pennsylvania Electric

This plant is also located in an area with less than 150 frost-free days. The 24-year-old unlined pond receiving bottom ash has a silt-clay/gravel substrate over the water table (at 12 meters), and receives about 10% coal-pile runoff in addition to bottom ash. Groundwater is only one and one-half to two meters below the surface at the 18-year-old landfill.

Sunbury, Pennsylvania Power and Light

This facility is located in an area that received no credit for generic characteristics. The ten-year-old fly ash pond has no other influents and a shaley-silt to shale/bedrock substrate. The bottom ash pond is 33 years old and reportedly receives 5% coal-pile runoff and 35% water treatment wastes. Water balance data were available as were priority pollutant analyses.

Bull Run, Tennessee Valley Authority

This plant is located in a region of heavy rainfall, but otherwise moderate climatic conditions. The combined fly and bottom ash pond is ten meters deep with groundwater located at five meters below the surface. Water balance data and priority pollutant analyses data were available.

Kingston, Tennessee Valley Authority

Regional conditions are very similar to those of the TVA facility described above. Monitoring wells with data records do exist, as do water balance and priority pollutant data. The present ash pond (fly and bottom ash combined) is surrounded on three sides by a large surface water body, a potential complicating factor. Metallic wastes from boiler cleaning are ponded separately in the old ash disposal area, which adjoins the present pond and appears to contribute some drainage to the present pond.

Sevier, Tennessee Valley Authority

This plant is in an area that received no credit for the generic characteristics. The unlined pond receiving fly and bottom ash is underlain by a natural substrate of one and one-half to three and one-half meters of medium to "lean" clay. Water balance data are available as are chemical analyses on priority pollutants. The new ash pond at this site drains toward the river, but the former ash pond, surrounded by the river, appears likely to intercept a significant fraction of that drainage.

Watts Bar, Tennessee Valley Authority

This plant is located in a region of excessive precipitation. Natural substrate under the nine-meter (30-foot) pond (combined fly and bottom ash) is composed of deep residual soils. Groundwater is located at about six meters (21 feet) from the surface. Water balance data are available as are data for some priority pollutants.

Clinch River, Appalachian Power

This facility is located in an area that received no credit for generic factors. The 22-year-old bottom ash interim pond has a bedrock layer one meter beneath it, and receives 51.1% other types of low volume waste, and reportedly has recycled effluent. The landfill, over shale, receives fly ash and some bottom ash, and is less than two years old. While some priority pollutant data existed, water balance data were available.

Glen Lyn, Appalachian Power

This is another facility that received no credit for generic factors. The 15-year-old fly ash interim pond is underlain by clay and reportedly receives only fly ash. The 17-year-old bottom ash interim pond receives 67% "other" low volume wastes in addition to bottom ash. The six-year-old landfill receives 90% fly ash and 10% bottom ash. Water balance data were available for this facility as were priority pollutant data. The disposal sites were reportedly close to the New River, with the ponds about 25 meters (80 feet) away and the landfill about 150 meters (490 feet) away. This provided the basis for crediting the ponds, but not the fill, because of possible drainage interferences from the ponds or other parts of the plant.

Amos, Appalachian Power

This facility is also in an area not credited for the generic factors. The fly ash interim pond receives only fly ash, is eight years old, and exists on about three to seven meters of silty clay, with the water table at five meters. The less than two-year-old fly ash landfill (unlined) receives 99% fly ash and 1% bottom ash, and is underlain by silty clay to the water table. The nine-year-old bottom ash pond receives at least 75% other wastes including pyrites, low-volume wastes, and cooling tower blowdown, and is set on similar substrate to the other disposal sites.

Kammer, Ohio Power

The fly ash from this facility is deposited in a pond that is shared with the Mitchell plant (see below). There were water balance data for bottom ash and fly ash, as well as data on known priority pollutants. The facility is located in an area that received no credit for generic factors. Final bottom ash disposal is by landfill off-site, but no data were available on that operation.

Kanawha River, Appalachian Power

The fly ash from this facility is deposited in an unlined landfill with no other influents. The bottom ash from Kanawha River is deposited in a 24-year-old pond with a PVC liner that is underlain by about two meters of alluvial silts and the water table at eight meters. The pond receives up to 67% low volume waste. There were water balance data and known priority pollutant data.

Mitchell, Ohio Power

The fly ash pond is unlined, 11 years old, and is shared with the Kammer facility. The pond is set in silty clay with the water table at four meters. There were fly ash and bottom ash water balance volume data and known priority pollutant data. The bottom ash is deposited in a polyethylene-lined five-year-old pond that overlies about two meters of sand and gravel and bedrock, with the water table at about eight and one-half meters. The pond receives significant amounts of miscellaneous wastes and is periodically excavated, two complicating factors.

Pleasants, Alleghany Power Systems

Since 1979, FGD wastes were stabilized by Dravo process using Calcilox® and ponded along with some fly ash. There was no other information available on site-specific factors. The plant is located in an area that received no credit for generic factors.

Sporn, Central Operating

This plant is in an area that received no credit for generic factors. The fly ash pond is 17 years old, unlined, and located over fine sand, with the water table at about 13 meters (43 feet). The pond received 69% low volume waste. A new landfill for ultimate disposal of the fly ash was to have two wells, but data availability was uncertain. Bottom ash from the Sporn plant is deposited in 29-year-old interim ponds in the same setting as the fly ash pond, and is then sold. There was water balance data on fly ash and bottom ash effluent and known priority pollutant data for the plant.

Other Plants

No information concerning disposal operations was available for the remaining sites. These plants are:

- Milliken, New York State Gas & Electric
- Armstrong, West Penn Power
- Hatfield, West Penn Power
- Mitchell, West Penn Power
- Newcastle, Pennsylvania Power
- Albright, Monongahela Power
- Fort Martin, Monongahela Power
- Harrison, Monongahela Power
- Mount Storm, Virginia Electric & Power
- Willow Island, Monogahela Power

Region C - New England

Merrimack, Public Service Co. of New Hampshire

This plant is located in an area with two favorably considered climatic factors: greater than 7000 degree days and fewer than 150 frost-free days per year. Other positive factors included the use of two mitigative controls, dry disposal and an apparently imported clay liner [25 cm (10 in.) thick] for the fly ash fill. The lined fill is more than two years old, and has over 50 cm (20 in.) of sandy silt and an equal depth of gravel, providing a reasonable expectation that leachate migration has taken place. The unlined bottom ash pond is over alluvial sands, also providing a leachate opportunity. Water balance and priority pollutant information were available for this plant.

Mercer, Public Service Electric & Gas

This plant is in an area which received no credit for any of the generic ratings factors. The only credit given to its combined, unlined fly ash/bottom ash interim pond was for the availability of water balance data. The off-site landfill was credited for dry disposal, but its study would be complicated by the need to account for effects of previous ponding operations.

Region D - Interior Lowlands

Colbert, Tennessee Valley Authority

The Colbert facility is located in the area of excessive precipitation. There are reportedly three meters (nine feet) of lean clay below the unlined pond that received combined fly and bottom ash and an unspecified amount of miscellaneous influents. There was baseline environmental data on bottom and fly ash water balance as well as at least 10 priority pollutants. The seven-year-old disposal pond at Colbert is adjacent to a small stream, which receives agricultural and road runoff just upstream of the disposal area.

Illinois Power Plants

For the Baldwin facility, there were water balance data for fly and bottom ash. Both Wood River and Hennepin have complicating factors that include greater than 10% miscellaneous influents. For Hennepin, there also was water balance information.

Central Illinois Public Service Plants

There are three Central Illinois Public Service plants for which information on waste type and disposal methods was not available (Coffeen, Hutsonville, and Meredosia). There were data on the volumes of bottom ash and fly ash discharge and water balance for both the Meredosia and Coffeen facilities.

Commonwealth Edison Plants

Crawford, Fisk, and Waukegan are three Commonwealth Edison facilities for which there was no information on waste type or disposal method. The Crawford and Fisk facilities both experience greater than 7000 degree days per year. All three facilities are in an area where there was reported significant potential for groundwater overdraft. Information on bottom ash and fly ash water balance was available for both the Crawford and Waukegan plants.

The bottom ash from Kincaid is disposed alone in a 12-year-old unlined pond over an unspecified depth of clay. The operation reportedly has recycled effluent and water balance data were available. The Powerton facility dry disposed of fly and bottom ash in a six-year-old landfill that was over sand/gravel, lined with Poz-o-pac. Powerton experiences about 7000 degree days annually and had six monitoring wells.

Duck Creek, Central Illinois Light

The Duck Creek facility is in a region characterized by greater than 7000 degree days per year. There was no other site-specific information on this facility.

Other Central Illinois Light Plants

The ponds at both the Edwards and Wallace facilities receive greater than 10% miscellaneous influents from station sumps. There was information on priority pollutants at both sites.

Joliet, Commonwealth Edison

The Joliet facility is located in an area characterized by 7000 degree days per year and where there was reported significant potential for groundwater overdraft. The unlined pond that receives combined fly and bottom ash is located in a limestone quarry. The pond is 15 years old and there are nine meters (30 feet) of limestone between the bottom of the pond and the water table. A complicating factor at this site is the fact that fly ash is subsequently to be dry disposed, perhaps within the timeframe of this study. There were four monitoring wells at the site and quarterly analysis was conducted at each for ammonia, barium, boron, iron, sulfate, and TDS.

Marion, Southern Illinois Coop

It was not know whether the fly ash/FGD landfill is lined. There also was no other information available on the specific characteristics of this site.

Newton, Central Illinois Public Service

There are four wells at the unlined landfill for stabilized FGD waste and fly ash but there was no report of monitoring data.

Will County, Commonwealth Edison

An unspecified combination of wastes is placed in an interim pond underlain by clay, and is then moved to the unlined landfill. This is considered a potential complicating factor. There were data on the bottom ash water balance. The facility is located in an area characterized by >7000 degree days per year and with reported significant potential for groundwater overdraft.

Bailly, Northern Indiana Public Service

The Bailly plant is in a region that may experience critical conditions for surface water utilization, and does experience more than 7000 degree days per year. Fly ash is disposed in an unlined landfill over sand, where the water table is reportedly at the surface of the fill. The fill received 100% fly ash, an advantage. Bottom ash is disposed alone in an unlined pond that overlies sand and reportedly had recycled effluent, a good study opportunity.

Breed, Indiana and Michigan Electric

The Breed plant is farther south than Bailly in a region where there are greater than 150 frost-free days and fewer than 7000 degree days per year. Bottom ash is disposed in a 17-year-old unlined pond that intersects groundwater. The pond receives 85% of its influent from floor drains and sumps, a complicating factor. Water balance data are available. Fly ash from this facility was expected to be disposed in an unlined landfill as of 1980. It was expected that this landfill would receive 100% fly ash but it would be too young for meaningful study in this program.

Brown, Southern Indiana Gas & Electric

The regional setting for this new (1979) facility does not experience extreme temperature fluctuations or precipitation. Neither groundwater nor surface water availability were reported critical. It was not known whether the fly ash/FGD waste fill is lined. No other site-specific information was available.

Public Service Company of Indiana Plants

This utility operates four plants for which there was no information available on waste type or disposal method (Cayuga, Gallagher, Gibson Station, and Wabash River). All of these plants are located in a region that experiences fewer than 7000 degree days per year, no precipitation extremes, and more than 150 frost-free days per year. The only site-specific information was for the Wabash River and Gallagher plants, for which there was water balance information.

Clifty Creek, Indiana-Kentucky Electric

One hundred percent fly ash is deposited in a 22-year-old pond, reportedly underlain by about 6.5 meters of clay and the water table. There were data on priority pollutants and water balance. One hundred percent bottom ash is deposited in one of two 24-year-old ponds where the water table is above the bottom of the pond. This pond is also underlain by about 6.5 meters of clay and shale but may be old enough for study. The second bottom ash pond receives 91% miscellaneous wastewater.

Culley, Southern Indiana Gas & Electric

Combined fly and bottom ash are deposited in two unlined ponds that are one and six years old, but underlain by unspecified substrate. There were water balance data for bottom ash and fly ash discharges, and both of these ponds reportedly had recycled effluents.

Hoosier, Hoosier Energy Division/Indiana Recreation

There was no information available on the waste type or disposal method at the Hoosier facility. This facility did not receive a positive rating for any regional factors.

Northern Indiana Public Service Plants

The Michigan City facility is located in a region that does not experience extreme temperature fluctuations. Here and at the Mitchell facility, surface water supply may be critical according to the Second National Water Assessment. Combined fly and bottom ash are deposited in five-year-old primary and secondary unlined interim ponds followed by off-site landfill. The ponds in series is a potential complication. Both ponds reportedly recycle effluent. The water table is reportedly above the bottom of both ponds, one of which is underlain by sand. No informaton was available on the off-site landfill.

There is no information available on the waste type or disposal method at the Mitchel or Schahfer facilities. Both plants are located in an area that experiences greater than 7000 degree days annually. No other site-specific information was available.

Petersburg, Indianapolis Power & Light

Fly ash and FGD sludge (since 1979) are disposed in an unlined landfill less than two years old. There are six wells at the fill but there were reportedly no background data yet available.

Other Indianapolis Power & Light Facilities

There was no information available on the waste type or disposal methods at either the Pritchard or Stout facilities, which received no credit for generic factors.

State Line, Commonwealth Edison-Indiana

This facility is located in Lake County, which experiences greater than 7000 degree days per year, and where surface water utilization may be critical. There were no other site-specific data available on the waste type or disposal method at this location.

Tanners Creek, Indiana & Michigan Electric

This plant is located in an area that received no credit for generic factors. Fly ash at this site is deposited in a pond with no other influent and lined with PVC and clay over sand. A negative factor is that the pond is only one year old. There were water balance data available as well as monitoring data from three wells. The effluent from this pond is recycled but to the bottom ash pond, creating another potential complication for the latter. The bottom ash is deposited in an unlined pond which also receives 75% wastewater. The water table is above the bottom of the pond. A portion of this pond has been covered and is being used as a parking lot.

Des Moines, Iowa Power & Light

This facility is located in a region that experiences about 7000 degree days, but not extreme precipitation. Groundwater and surface water utilization were not reported to be critical. There was no information on waste type or disposal method. Water balance for bottom ash and fly ash discharge was available.

George Neal, Iowa Public Service

The George Neal plant is also located in the region that experiences extreme temperature fluctuations and about 150 frost-free days per year. Combined fly and bottom ash are deposited in three different unlined ponds, all of which are old enough for their leachates to conceivably have reached the water table eight meters below.

Interstate Power Plants

Both Kapp and Lansing are located in regions where groundwater and surface water utilization were not reported critical. There are extremes of temperature in these regions and fewer than 150 frost-free days at Lansing. At both facilities the water table was reported to be three meters or less below the bottom of the ponds and both ponds are old enough for leachate to have potentially reached the water table. The side berms at the Lansing plant are covered with bentonite clay. There were bottom ash and fly ash discharge water balance data for the Lansing facility.

Kentucky Utility Plants

The Kentucky Utility plants (Brown, Ghent, and Green River) are all located in a region that does not experience extremes in temperature or precipitation. Groundwater and surface water utilization were not reported to be critical. There are more than 150 frost-free days per year in these areas. Combined fly and bottom ash are deposited in unlined ponds at both the Brown and Ghent facilities. Neither of these ponds recycle effluent and both receive greater than 60% service water. There were water balance data on bottom and fly ash discharges at both Brown and Ghent.

For the Green River facility, there were water balance data on bottom and fly ash discharge. There was no other site-specific information available on this facility.

Cane Run, Louisville Gas & Electric

This facility is located in an area that received no credit for generic factors. Fly ash, bottom ash, FGD sludge, and about 8% miscellaneous influent are deposited in an interim pond and then in a landfill. The pond is about three years old and is underlain by one to one and one-half meters of clay. There are 20 to 25 meters (65 to 80 feet) of sand between the clay and the water table. There were water balance data and data on priority pollutants. The landfill is about one year old and is lined with Poz-o-pac. There will be monitoring wells on the site. Groundwater contamination from other proximate sources may be a complicating factor.

Big Rivers Rural Electric Coop Plants

This utility operates two plants in Region D, Reid and Coleman. There was no information available on the waste type or disposal method at either of these facilities. They are both located in regions where temperature extremes and precipitation extremes are not characteristic, and where groundwater and surface water utilization were not reported to be critical. There were water balance data and information on priority pollutants available for the Reid facility.

East Kentucky Rural Electric Coop Plants

Two facilities operated by this utility are Cooper and Spurlock. There was no information available on waste type or disposal methods for either plant. Both facilities are located in a region with less than 7000 degree days and where surface water and groundwater utilization were not reported critical. The Cooper facility is located in a region where precipitation of more than 120 cm (48 in.) per year is common.

Mill Creek, Louisville Gas & Electric

This facility was scheduled to dispose of fly ash, bottom ash, and FGD sludge in a three-year-old clay-lined pond until the early 1980's when the waste was to be deposited in a lined landfill (22). This change is a complicating factor. There were water balance and priority pollutant data available for the pond. The fill was to be underlain by clay or lined with Poz-o-pac, with coarse silt and sand to a depth of 20 meters (65 feet) below the liner. This facility is located in a region where there are neither extreme temperatures nor extremes in precipitation. There are more than 150 frost-free days per year and neither groundwater nor surface water utilization were reported to be critical.

Paddys Run, Louisville Gas & Electric

The regional characteristics for this facility are the same as for Mill Creek. The fly ash and FGD sludge from this facility are mixed with lime and deposited in a six-year-old landfill underlain by clay, sand, and bedrock in layers of unspecified depth. A land use issue may exist as the completed fill is to be turned over to the county. Combined fly and bottom ash from the facility are also disposed of along with about 7% miscellaneous influent, in a clay-bottomed pond. The pond is 30 years old and is set in about 30 meters (100 feet) of sand. There were water balance and priority pollutant data available. As for Cane Run, groundwater contamination from other sources may be a complicating factor.

Paradise, Tennessee Valley Authority

The regional factors for this facility are the same as for Mill Creek. Water balance and priority pollutant data were available. Bottom ash is subsequently taken to a mine for landfill, with the prior ponding a complicating factor.

Smith, Owensboro Municipal Utilities

Again, the same regional setting prevails. Combined fly and bottom ash at this facility are deposited in an unlined pond, 15 years old, overlying sand. The pond receives 10% boiler blowdown and 5% coal-pile runoff. The water table is reportedly above the bottom of the pond (about one and one-half meters down). There were water balance data and priority pollutant data available. After interim ponding, fly ash is also deposited in a landfill (in a mine), but no data were available for this operation.

Union Electric Plants

Combined fly and bottom ash are deposited in seven- and 11-year-old unlined ponds at the two Union Electric facilities, Labadie and Sioux. There were water balance data available for both ponds. Both facilities are located in regions that did not receive credit for any generic factors.

Sibley, Missouri Public Service

There was no information available on the waste type of disposal method at the Sibley facility. Regional characteristics are as for the Union Electric plants, except that Jackson County is in an area of reported inadequate surface water supply. There were water balance data available for bottom ash and fly ash discharge.

Thomas Hill, Associated Electric Coop

There was no information available on the waste type of disposal method at the Thomas Hill facility, which is in an area with the same characteristics as the Union Electric plants.

Toledo Edison Plants

The two Toledo Edison plants, Acme and Bay Shore, are located in a county with none of the regional characteristics given ratings credit. One hundred percent of Acme's fly ash is deposited in a seven-year-old, unlined pond. There were water balance and priority pollutant data available for the plant. Bottom ash is landfilled off-site, but there were no data on that operation. The Bay Shore facility deposits fly ash in an unlined four-year-old pond for which water balance and priority pollutant data were available.

Cincinnati Gas & Electric Plants

Two plants operated by this utility (Beckjord and Miami Fort) are located in regions where none of the generic ratings criteria were credited. Both facilities dispose of fly ash in nine 11-year-old unlined landfills over substrate whose type was unspecified. Combined fly ash and bottom ash are disposed of in 20-year-old unlined interim ponds followed by the unlined landfills at both facilities. The water tables (3 to 16 meters down) may have been reached by leachate from the old ponds. There were water balance data and priority pollutant data for each plant in addition to monitoring wells around the ponds, for which data were available on a variety of chemical species.

Dayton Power & Light

There were no data available on the waste type or disposal method used at three plants operated by this utility (Hutchings, Stuart, and Tait). All three sites are located in regions that received no rating credits for generic factors. There was no other site-specific information for any of these sites.

Other Tennessee Valley Authority Plants

The Cumberland and Gallatin plants are both located in regions that receive more than 120 cm of precipitation annually, but meet none of the other criteria for generic credits. There were priority pollutant and water balance information available for both ponds.

Region E - Ozark

Union Electric Co. Plants

These plants, Meramec and Rush Island, near St. Louis, received no credit for climatic or other generic factors. The unlined, combined fly ash/bottom ash disposal pond at Meramec, but not Rush Island, was credited because of the availability of water balance data, but little other information was available on either plant.

Southwest, Springfield City Utilities

The combined fly ash/bottom ash/FGD landfill was credited for the availability of influent data, dry disposal, and the use of a compacted ash/lime/soil liner under the fill. Negative factors were that the fill is about two years old and underlain by three to five meters (10 to 16 feet) of silty clays, and that the fill receives bottom ash after it is interim ponded. The bottom ash pond reportedly is the same age and set on the same type of substrate as the fill; water balance data were available.

Region F - Great Lakes

Campbell, Consumer's Power

This plant is in an area that experiences more than 7000 degree days annually. Its combined ash ponds were seven and 17 years old, and set in sand, rated favorably. Water balance information was available.

Cobb, Consumer's Power

This plant was also in an area experiencing greater than 7000 degree days and also less than 150 frost-free days annually. The fly ash and bottom ash interim pond is 15 years old, set on a sand and decomposed wood substrate. Water balance information was available. The final landfill for fly ash and bottom ash was also set on wood chips and sand, and was eight years old. Its composition was reported to be entirely of fly ash and bottom ash.

Conners Creek, Detroit Edison

This facility is set in an area that received no credit for generic factors. The interim fly ash and bottom ash pond is about 40 years old, but the underlying substrate is unknown. This pond is lined with concrete and receives 30% "other" influents. Water balance and priority pollutant data were available. The fly ash landfill is greater than 20 years old, with about five meters of clay substrate. However, it is next to a limestone quarry and reportedly saline water and wastes from several other plants enter the fill, two complicating factors. Landfill composition was reported.

Eckert, Lansing Board of Water & Light

This facility is in an area experiencing fewer than 150 frost-free days annually. No site-specific environmental information was available.

Marysville, Detroit Edison

This facility is in an area that received no credit for generic factors. The combined fly ash/bottom ash pond is only about one year old and set in about 30 meters of clay (100 feet), which was rated negatively. The pond also received 80% of other influents and was adjacent to the coal-pile runoff pond. Priority pollutant data were available, and the pond effluent was reportedly recycled. The fly ash and bottom ash landfill at St. Clair served this plant as well.

Monroe, Detroit Edison

The Monroe plant also received no credit for generic factors. The fly ash pond is reportedly only five years old, underlain by 10 meters (33 feet) of clay. Water balance data were available, and the pond was credited for being comprised of 100% fly ash. The bottom ash pond was reportedly over a shallower layer of clay (three to seven meters) and of the same age. However, it reportedly received 40% miscellaneous influents.

Presque Isle, Upper Peninsula Generating Company

This plant is located in an area that experiences greater than 7000 degree days and fewer than 150 frost-free days annually. The bottom ash pond was reportedly 15 years old but located in unspecified substrate, and in the process of being phased out. The pond was credited for being 100% bottom ash and for the available water balance information. The combined fly ash/bottom ash landfill was reportedly 11 years old and about 18 meters (60 feet) above the water table. Its composition was reported to be 80% fly ash and 20% bottom ash.

River Rouge, Detroit Edison

This facility is in an area that received no generic credit. The bottom ash/fly ash landfill for the wastes from this plant is also used for wastes from the Conners Creek plant. The interim bottom ash pond is about 30 years old and set in about 33 meters (110 feet) of clay. The drainage to the pond is comprised of about 14% miscellaneous influents. There is some question as to whether or not the effluent from the pond is recycled; priority pollutant data were available.

St. Clair, Detroit Edison

This plant received no credit for generic factors. The bottom ash interim pond was reportedly about 40 years old, set in about 30 meters of clay. The final fly ash and bottom ash landfill is the one also used by the Marysville Station. This was a complicating factor, along with the fact that interim ponded wastes were finally disposed of in this fill. The setting for this fill was reportedly the same as for the fly ash/bottom ash pond, but the fill is about 30 years old. A potential land use issue exists as the site is reportedly to be used for recreation after the cessation of the disposal operations.

Trenton Channel, Detroit Edison

The facility received no credit for generic factors. The combined fly ash and bottom ash interim pond is reportedly set in about seven meters (23 feet) of clay and miscellaneous fill, and is about 20 years old. Priority pollutant and water balance data were available. The final disposal of fly ash and bottom ash from this plant occurs in the Conners Creek landfill.

Whiting, Consumer Power

Disposal information was unavailable for this plant, and it was in an area that received no generic credit. It was credited for the availability of water balance data.

Dunkirk, Niagara Mohawk Power

This plant is in an area that experiences less than 150 frost-free days per year. The fly ash and bottom ash interim pond is about 19 years old and set in an unspecified substrate. It reportedly received about 60% miscellaneous influent, although this data may be for more than one pond. Water balance data were available, as was an indication that the pond effluent was recycled. The fly ash landfill is about 14 years old, set over about two to three and one-half meters of clay and then shale with the water table at about five meters. Baseline studies of groundwater, surface water, and biotic impacts have been conducted here by the Department of Energy. The fly ash landfill is close to a small stream and the opportunity to study aquatic biota in that stream exists. Landfill composition data were available.

were

Huntley, Niagra Mohawk Power

This facility is set in an area that experiences greater than 7000 degree days per year. The eastern part of the county experiences fewer than 150 frost-free days per year. The bottom ash interim ponds are between three and 50 years old, and their bottoms about one and one-half meters above the water table. Two of these ponds are reportedly lined, one with clay and one with concrete, providing a good study opportunity. Water balance data was available. The fly ash and bottom ash landfill at this facility is about nine years old, set in brown clay, with the water table at about eight meters. Composition of the landfill was reported to include 84% fly ash and 16% bottom ash. A potential land use issue exists in that the fill is reportedly planned for subsequent utilization for an industrial park.

Rochester #7 (Russell Station), Rochester Gas & Electric Corporation

This facility received no credit for generic factors. Because of the unusual age distribution of the disposal facilities, none were rated highly.

Columbia I, Wisconsin Power & Light

This facility is an area that experiences more than 7000 degree days annually. The fly ash pond from this facility is about four years old, with a variable water table from the surface to three meters below. It is near a small surface water stream, Duck Creek. Baseline studies have been conducted at this site by the University of Wisconsin and EPA/Duluth. Opportunities for further study of aquatic biota exist in the small stream, and effluent recycle is reportedly practiced for the fly ash pond. The bottom ash pond reportedly has the same setting characteristics as the fly ash pond.

Edgewater, Wisconsin Power & Light

This facility was also credited for being in an area experiencing greater than 7000 degree days annually, as well as being in an area of reported surface and groundwater overdraft. The combined fly ash and bottom ash pond is set in silty sand, with the water table at the surface to three meters below. No miscellaneous influents are reported to enter the pond. Water balance and priority pollutant data were available, as were data from seven monitoring wells.

Genoa #3, Dairyland Power Cooperative

This facility was credited for being in an area that experiences greater than 7000 degree days and fewer than 150 frost-free days annually. The combined fly ash and bottom ash pond is reportedly three years old, and set in an area of coarse and fine sands with the water table at three meters. Water balance and priority pollutant data were available, as were data from 10 monitoring wells.

Nelson Dewey, Wisconsin Power & Light

This facility was in an area experiencing greater than 7000 degree days. The combined fly ash and bottom ash pond is reportedly 20 years old, set in sandy silt and gravel, with a water table between the surface and three meters below. Water balance and priority pollutant data were available, along with data from 22 wells. The ponds reportedly received no miscellaneous influents.

Region G - Superior

Black Dog, Northern States Power Company

The interim fly ash/bottom ash pond at this facility is about five years old, with the water table about three meters below the surface. However, no information was available on the type of substrate in between. Water balance information for the plant was available.

Clay Boswell, Minnesota Power & Light

This facility has separate fly and bottom ash ponds, six years old, set in <one meter of clay over about one meter of sand, with the water table at a little over a meter below the surface. Evaluation of both ponds is potentially complicated since it appears that the plant will go to a new disposal system in 1980. Water balance information was available as were data from 21 monitoring wells.

High Bridge, Northern States Power

No information was available on the disposal operation at this plant.

A.S. King, Northern States Power Company

The combined fly ash and bottom ash fill at this plant is about seven years old, set in about six meters (20 feet) of silty clay sand over sand, and finally sandstone. There was an indication that piezometers had been installed, but data availability was uncertain. The landfill was reportedly half fly ash and half bottom ash.

Riverside, Northern States Power Company

The combined fly ash and bottom ash landfill for this facility is set in a mixture of silty clay, silty sand, and sand, with the water table at about seven meters (23 feet). However, the age of the fill was unavailable. The reporting of both 5% "bottom ash" and 35% "slag" was somewhat incongruous in the description of the fill composition. A potential land use issue exists in that the site has reportedly been designated for use as commercial property after disposal operations.

Sherburne County, Northern States Power Company

The combined fly ash and FGD sludge pond for this facility is about four years old and has a one-half-meter-thick artificial placed clay liner over the underlying sand, a positive factor. The Mississippi River is apparently within about 120 meters (400 feet) of the facility. Data were apparently available from eight monitoring wells, and effluent recycle is reportedly practiced for the pond. There was no information available on the bottom ash pond at this facility.

Big Stone, Otter Tail Power Company

The bottom ash and fly ash interim pond at this facility is about four years old and set in clay and sandy clay about 40 meters (130 feet) above the water table, a negative factor. Effluent recycle is reportedly practiced. The fly ash and bottom ash landfill for the facility is also about the same age and in the same type of setting. Data on the composition of the landfill indicated that it was 70% bottom ash and 30% fly ash.

Regions H-M, Great Plains and West

Comanche, Public Service of Colorado

This plant is located in an area that does experience very low precipitation and where demand for existing water supplies was reported to be critical. The St. Charles River is adjacent to the landfill (fly ash and bottom ash in separate fills) areas, providing a layout potentially suitable for study of non-point impacts on surface waters. The pond and landfill sites are about six years old, but the nature of the underlying substrate remains unspecified.

Jeffrey, Kansas Power & Light

This plant is located in an area of less extreme precipitation, but one where demands on existing water supplies have reportedly reached a critical level. Bottom ash and FGD wastes are co-disposed in a pond reported to have a placed lining, with water recycle in practice. Fly ash disposal practices were not known at the time of rating.

LaCygne, Kansas City Power & Light

This facility is not located in an area of extreme climatic conditions and demand for existing water supplies was not reported to be critical. Water recycle is reportedly practiced for the bottom ash pond.

Hawthorn, Kansas City Power & Light

As with the above site, this plant is not located in an area of extreme climatic conditions, but is near the area with reported water supply shortages.

Incomplete information concerning disposal operations was available for the four remaining sites in Region H. These plants are:

- Lawrence, Kansas Power & Light,
- Asbury, Empire District Electric,
- Montrose, Kansas City Power & Light, and
- Harrington, Southwestern Public Service.

Colstrip, Montana Power

Colstrip is in an area of very low rainfall (35 cm/yr), high evaporation, and extremes in temperatures. The combination of ponding steps is a potential complicating factor. Several monitoring wells already exist around various disposal ponds, potentially affording useful background data. Water recycle is practiced for the final pond drainage and bottom ash waste stream. Study opportunities for terrestrial biota appear to be available because of previous surveys. The extent to which natural clays or imported materials constitute the reported one-meter clay liners for several of the ponds is unclear.

North Omaha Station, Omaha Public Power

This plant is located in an area that experiences fewer of the climatic extremes more typical of other areas included in this subregion. The existing 10-year-old landfill is located on alluvial clay, depth uncertain.

USE THIS SHEET FOR REPORT TYPING 8 1/2 x 11

TOP

Sheldon Station, Nebraska Public Power District

This facility is located in a setting similar to that of the previous plant. Water supply may be a critical regional issue. The two-year-old landfill is located on a natural silty clay layer that is about 20 meters (61 feet) deep, indicating conditions unfavorable to detection of contaminant migration.

Leland Olds, Basin Electric Power Cooperative

This plant is located in an area of low rainfall, temperature extremes, and very short frost-free periods. Four ponds exist on this site, ranging in age from 1.5 to 15 years old, on unspecified substrate and overlying the water table five meters below the surface. Water balance data were available. Reportedly, 1% of pond influent is wastewater treatment plant sludge.

Young, Minnkota Power Cooperative

The Young Station is located in an area of temperature extremes, with precipitation levels slightly above 40 cm per year. The two-year-old FGD system is a closed system, with water recycle. The landfill for these wastes is the nearby mine site from which coal is being removed, providing a potential land use issue regarding interface with the Surface Mining Control and Reclamation Act. Monitoring wells alreay exist on this site, but there is a good chance that the operation is too young to provide leachate study conditions. The construction of new ponds for solid wastes is also a potential complication.

Dave Johnston, Pacific Power & Light

The Johnston plant is in an area of very extreme climatic conditions, especially in terms of precipitation and frost-free period. Surface water demands may be resulting in strains on supplies in this very arid region. For two of the disposal ponds, some water recycling also occurs. Miscellaneous plant trash also goes to the fly ash landfill area. Water balance data exist, and groundwater wells were installed at this site over a year ago. The plant and disposal areas are adjacent to a river and small creek, affording potential for study of non-point surface water impacts. Biotic impacts may be worthy of analysis, as it is a fishing area and terrestrial game species and raptors are a significant presence on and near the disposal areas. The age of the oldest landfill areas (20 years) combined with the underlying alluvial sandy substrate appear promising for investigation of leachate migration.

10 Lines to End of Typing Area

Coal Creek, Cooperative Power Association

No site-specific information was available for this site. Three regional/generic factors due to the location were credited in the ratings.

For Page Numbering

USE THIS SHEET FOR REPORT TYPING 8½ X 11

TOP

Cholla, Arizona Public Service

While precipitation levels are low, demand for existing water supplies had not reached critical levels as reported in the Second National Water Assessment.

Arapahoe, Public Service of Colorado

Water supply, precipitation, and temperature conditions for the area are those described above as typical of Region J. A potential complicating factor is landfilling of dredgings from old interim ponds. It was not known whether the disposal areas are lined. Water balance data were available and pond effluent recycling is reportedly practiced.

Cherokee, Public Service of Colorado

The climatic/environmental conditions of this plant are essentially the same as those described above, although somewhat less than 7000 degree days appear to be typical. The less-than-two-year-old landfill, which is bentonite/clay-lined, receives both bottom and fly ash (1:3 ratio). The interim pond is 15 years old. Water balance data also were available.

Drake, Colorado Springs Department of Public Utilities

Environmental conditions at this plant are similar to those at the preceding facility. The combined fly and bottom ash landfill (clay-lined) is only two years old and receives essentially bottom and fly ash only (<1% "other" wastes). Six wells are in place, with some water quality data available.

Hayden Station, Colorado Utilities Electric Association

Climatic conditions here are more extreme than those at the plants described above, although water supply was not reported to be in a critical state. The unlined landfill is five years old and over 0-30 meters of unconsolidated material. Water balance data were available, and while three wells were reported to be present, only water level data were known to be available. The landfill area runoff drains to Grassy Creek.

10 Lines to End of Typing Area

Four Corners, Arizona Public Service

Precipitation is extremely low (0-20 cm) in this area and water supply may be a critical issue. While the frost-free period is short, temperature extremes are moderated somewhat. Little information was available concerning the disposal operations; water balance and some priority pollutant data were available. The planned installation of an FGD system in the recent past was considered a potential complicating factor.

For Page Numbering

ADL-054 1279 200M

San Juan, Public Service of New Mexico

The environmental/climatic conditions at San Juan are similar to those described for Four Corners. Relatively little information was available concerning the seven-year-old disposal operations. Eight wells do exist on site, but data content and availability were not known.

Hunter, Utah Power & Light

While precipitation is extremely low, water supply was not reported to be critical in the area of this facility. Temperature extremes did not meet the criteria for credit. The approximately two-year-old landfill is unlined, but has one to ten feet of compacted silty clay underlying it, conditions less than favorable for the study of leachate migration.

Huntington, Utah Power & Light

With a similar location to Hunter, environmental/climatic conditions at Huntington are similar to those described above. Both the pond (bottom ash) and an old landfill (fly ash and FGD waste) are unlined and the latter (at least) is placed over a gravel, sandstone/shale substrate.

Jim Bridger, Pacific Power & Light

This facility is located in a region of extreme temperatures and low precipitation. Water supply was not reported to be critical here, although severe depletions were reported for adjacent areas. Since about five years ago, bottom ash and fly ash are being directly landfilled dry in the adjacent coal mine. The irregular terrain of the mine (ranging over more than 30 meters in elevation) is a potential complicating factor. Eight monitoring wells exist and data are available on water quality and landfill compositions. A new FGD pond was being constructed at this plant.

Other Plants

No information concerning site-specific conditions was available for the Navajo and Naughton facilities.

Apache, Arizona Electric Power Cooperative

At the Apache facility, the natural substrate under the new combined waste pond is approximately three to five meters (10 to 15 feet) of clay/organic matter over sand. Water recycle is reportedly practiced.

Gardner, Nevada Power

At this facility, what fly ash remains is landfilled directly with bottom ash at an unlined fill about seven years old. The age and substrate combination at the seven-year-old unlined pond, set in 17 meters of clay, appears unfavorable for leachate migration. There are two monitoring wells around the FGD pond, but the nature and extent of data from the wells were unavailable. The area reportedly experienced significant groundwater overdraft.

Mohave, Southern California Edison

This plant is also in an area reported to experience significant groundwater overdraft. Potential complicating factors are the delivery of coal by slurry pipeline and the boiler blowdown used to wet down the landfill. The landfill is over seven years old and on a substrate of sand and gravel with a five-meter clay lens at about 28 meters. Monitoring wells exist at this site, but data availability was uncertain.

Centralia, Pacific Power & Light

The unlined interim pond also receives 20% cooling tower blowdown. This seven-year-old pond has a substrate of about one to three meters of compacted sandy clay, three to five meters of peat clay, and 15 to 21 meters of silt clay; the water table sometimes reaches the ground surface in the area. Pond effluent recycle is practiced. Fly ash and bottom ash are finally disposed in the adjacent coal mine. Local sandy clay is placed in the mine prior to the ash wastes.

APPENDIX B

HYDROGEOLOGIC AND GEOTECHNICAL PROCEDURES MANUAL

FULL-SCALE FIELD EVALUATION OF WASTE DISPOSAL FROM COAL-FIRED ELECTRIC GENERATING PLANTS

By

Allen W. Hatheway
John T. Humphrey
Haley & Aldrich, Inc.
Cambridge, Massachusetts 02142

Barry K. Thacker
David Cowherd
Bowser-Morner
Testing Laboratories, Inc.
Dayton, Ohio 45401

EPA Contract 68-02-3167

EPA Project Officer: Julian W. Jones
Industrial Environmental Research Laboratory*
Office of Environmental Engineering and Technology
Research Triangle Park, North Carolina 27711

Prepared For

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

(*) Now, the Air and Energy Engineering Research Laboratory

PREFACE

This manual establishes administrative and technical procedures for conducting field explorations and instrumentation installations for selected site investigations relating to U.S. Environmental Protection Agency (EPA) Contact 68-02-3167, "Characterization and Environmental Monitoring of Full Scale Utility Waste Disposal Sites" with Arthur D. Little, Inc. of Cambridge, Massachusetts.

This Manual entitled, "Hydrogeologic and Geotechnical Procedures Manual", is one of four manuals which will govern and control the various aspects of field and laboratory testing and analysis for evaluating selected utility waste disposal sites.

Preparation of this Manual was primarily a joint effort between Haley & Aldrich, Inc., Cambridge, Massachusetts and Bowser-Morner Testing Laboratories, Inc., Dayton, Ohio. The principal authors, Allen W. Hatheway and John T. Humphrey of Haley & Aldrich (H&A) and Barry K. Thacker of Bowser-Morner (B-M) would like to acknowledge with gratitude the various organizations and personnel who also contributed to various sections and reviews of this Manual; especially Chakra J. Santhanam, Arthur D. Little (ADL) Project Director.

Arthur D. Little, Inc.:	David E. Kleinschmidt Itamar Bodek James R. Valentine
Haley & Aldrich, Inc.:	Thomas K. Liu John A. Mosher Janice R. Hight
Bowser-Morner Testing Labs:	David C. Cowherd Scott D. Kinney
University of Louisville:	D. Joseph Hagerty C. Robert Ullrich

CONTENTS

Section Page(B-)

1. INTRODUCTION 1-1
    - 1.1 OVERALL PROGRAM 1-1
    - 1.2 PURPOSE 1-3
    - 1.3 MANUAL ORGANIZATION 1-4

2. TEAM RESPONSIBILITIES AND COORDINATION 2-1
    - 2.1 BASIC RESPONSIBILITIES OF TEAM MEMBERS 2-1
    - 2.2 SEQUENCE OF FIELD ACTIVITIES 2-2
    - 2.3 COMMUNICATIONS 2-3
    - 2.4 COST CONTROL RESPONSIBILITIES 2-4
    - 2.5 PROJECT REPORT RESPONSIBILITIES 2-4

3. SITE SELECTION AND TEST PLAN PREPARATION (TASK I) 3-1
    - 3.1 SITE SELECTION OBJECTIVES 3-1
    - 3.2 SITE REFERENCE MATERIALS 3-1
    - 3.3 PRELIMINARY SITE RECONNAISSANCE VISITS 3-2

4. SITE EVALUATION (TASK II) 4-1
    - 4.1 GENERAL 4-1
    - 4.2 BORING LOGS 4-2
    - 4.3 EXPLORATORY BORINGS IN DISPOSAL WASTE 4-2
    - 4.4 EXPLORATORY BORINGS IN DISPOSAL PONDS 4-7
    - 4.5 HYDROGEOLOGICAL EXPLORATIONS 4-8
    - 4.6 PERMEABILITY TESTS 4-9
    - 4.7 IN-SITU CHEMICAL TESTING (SCT) 4-9
    - 4.8 VARIATIONS IN SITE MODELS 4-9
    - 4.9 IDEALIZED SITE EVALUATION SCHEMES 4-10
        - 4.9.1 Thin Sand Deposit 4-10
        - 4.9.2 Thick Sand Deposit 4-11
        - 4.9.3 Two Distinct Sand Seams Separated by Relatively Impervious Materials 4-13
        - 4.9.4 Silt or Clayey Sand Deposits 4-13
        - 4.9.5 Alternating Strata, Clay and Sand 4-13
        - 4.9.6 Sand and Gravel 4-13
    - 4.10 TYPICAL QUANTITIES FOR SITE EVALUATION 4-16
    - 4.11 FIELD EXPLORATION AND TECHNICAL PROCEDURES 4-17
    - 4.12 QUALITY CONTROL 4-17
    - 4.13 TEST PIT EXCAVATIONS 4-18
    - 4.14 ADDITIONAL SITE TASKS 4-18
    - 4.15 ADDITIONAL COMMENTS ON SAMPLING AND ANALYSIS 4-18
    - 4.16 UTILITY INTERFACING 4-20
    - 4.17 USE OF METRIC SYSTEM 4-20
    - 4.18 FINAL SITE REPORTS 4-20

LIST OF FIGURES

Figure		Page(B-)
1.	WASTE SAMPLING AND TESTING MODEL Case A - Dry Fill, Case B - Wet Pond	4-5
2.	SITE DEVELOPMENT MODEL Case 1 - Thin Sand Deposit Case 2 - Thick Sand Deposit	4-12
3.	SITE DEVELOPMENT MODEL Case 3 - Sand Seams Separated by Clay Strata Case 4 - Silt or Sandy Clay Deposit	4-14
4.	SITE DEVELOPMENT MODEL Case 5 - Alternative Strata of Clay and Sand Sampling through Wet Pond	4-15

LIST OF TABLES

Table		Page(B-)
1.	PRINCIPAL PARTICIPANTS EPA CONTRACT NO. 68-02-3167	1-2
2.	OUTLINE FOR SITE TEST PLAN APPROACH AND REPORT	3-4
3.	APPROXIMATE TESTING ALLOCATION - DRY FILL	4-6
4.	APPROXIMATE TESTING ALLOCATION - WET POND	4-7
5.	TYPICAL SITE EVALUATION QUANTITIES	4-16
6.	FINAL SITE EVALUATION REPORT SUMMARY	4-21

EXHIBIT A
SPECIFICATIONS FOR SUBSURFACE EXPLORATION

Section Page(B-)

1. GENERAL CONDITIONS A-1

1.01 General A-1
1.02 Participating Parties A-1
1.03 Definitions A-2
1.04 The General Work Agreement A-3
1.05 Personnel, Equipment, Commencement and Methods A-3
    1.05.1 Qualified Personnel A-3
    1.05.2 Plant and Equipment A-3
    1.05.3 Commence Work A-4
    1.05.4 Methods, Recording A-4

1.06 Payment A-4
1.07 Execution and Completion of Work A-5
    1.07.1 Requirements A-5
    1.07.2 Permits A-6
    1.07.3 Barricades and Warning Signs A-7
    1.07.4 Public Convenience and Safety A-7
    1.07.5 Protection of Property A-8

1.08 Liability and Responsibility of Contractor A-9
1.09 Equal Employment Opportunity A-11
1.10 Subcontractors A-11
1.11 Clean Air Act of 1976 A-11
1.12 Boring Foreman A-12
1.13 Inspection of Work A-12
1.14 Locations A-13
1.15 Authority of the Hydrogeologist and the Geotechnical Engineer A-13
1.16 All Laws and Regulations A-14
1.17 Insurance A-14
1.18 Accidents A-16
1.19 Ownership of Data A-16
1.20 Miscellaneous A-17

2. TECHNICAL PROVISIONS A-18

2.01 Conduct of the Work A-18
2.02 Borings A-19
    2.02.1 General A-19
    2.02.2 Type A-19
    2.02.3 Number, Location and Estimated Depth A-19

Section			Page(B-)
2.03	Boring Installation		A-20
	2.03.1	General	A-20
	2.03.2	Drilling Method	A-20
	2.03.3	Drilling Water	A-20
	2.03.4	Flight Augers	A-21
	2.03.5	Uncased Holes	A-21
	2.03.6	Casing	A-21
	2.03.7	Casing Size	A-22
	2.03.8	Removal of Casing	A-22
2.04	Soil Classification System		A-22
	2.04.1	Color	A-23
	2.04.2	Grain Size	A-23
	2.04.3	Relative Compactness	A-25
	2.04.4	Relative Consistency	A-25
	2.04.5	Relative Moisture	A-26
	2.04.6	Description	A-26
2.05	Split-Spoon Sampling		A-26
	2.05.1	Sampling	A-26
	2.05.2	Recovery	A-27
	2.05.3	Standard Penetration	A-27
	2.05.4	"Refusal"	A-28
2.06	Rock Coring		A-28
2.07	Stationary Piston Tube Sampling		A-29
2.08	Thin-Wall Tube Sampling		A-32
2.09	Field Vane Shear Testing		A-32
2.10	Groundwater Observation Wells		A-34
2.11	Piezometers		A-37
2.12	Water Quality Sampling		A-44
2.13	Grouting		A-46
2.14	Field Permeability Tests		A-46
	2.14.1	General	A-46
	2.14.2	Rising Water Level Method	A-47
	2.14.3	Falling Water Level Method	A-48
	2.14.4	Constant Water Level Method	A-49
2.15	Test for Running Sand		A-50
2.16	Machine Excavated Test Pits		A-50
2.17	Preserving Samples		A-52
	2.17.1	Split-Spoon Samples	A-52
	2.17.2	Rock Cores	A-52
	2.17.3	Thin-Wall and Stationary Piston Tube Samples	A-53

Section Page(B-)

2.18 Submission of Samples A-54
2.19 Records A-54

  2.19.1 General Information A-54
  2.19.2 Rock Cores A-55
  2.19.3 Miscellaneous Data A-56

2.20 Drilling Procedure for Measuring Density of Waste Stockpiles Using Nuclear Depth Density Equipment A-56

  2.20.1 Equipment A-56
  2.20.2 Procedure A-57

2.21 Test Pit Procedure for Measuring Density of Waste Stockpiles Using Nuclear Density Equipment A-59

  2.21.1 Equipment A-59
  2.21.2 Procedure A-59
  2.21.3 Depth Density Gauges Model 1251 and 1351 Connections A-60
  2.21.4 Field Calibration for Standard Counts A-62
  2.21.5 Direct Moisture or Density Readings A-62
  2.21.6 General Requirements A-64

2.22 Environmental Precautions A-64

  2.22.1 Legal Requirements A-64
  2.22.2 Access Roads A-64
  2.22.3 Drilling A-65

LIST OF FIGURES

Figure		Page(B-)
A	Unified Soil Classification System	A-24
B	Lockable Protective Casing Detail	A-36
C	Observation Well (Averaging Type)	A-38
D	Observation Well (Isolated Type)	A-39
E	Multiple Piezometer/Observation Well Installation	A-41
F	Piezometer Pressure Measurement Gauge	A-45

EXHIBIT B
FIELD EXPLORATION FORMS

Form Number		Page(B-)
H&A 26	Daily Report - Test Borings	B-1
H&A 4	Test Boring Report (Pg. 1)	B-2
H&A 4A	Test Boring Report (Pg. 2)	B-3
H&A 24	Test Pit Report	B-4
H&A 59	Groundwater Observation Well Report	B-5
H&A 59A	Groundwater Monitoring Report	B-6
H&A 60	Piezometer Installation Report	B-7
H&A 73	Borehole Sealing Report	B-8
H&A 72	Vane Shear Report	B-9
H&A 69	Field Permeability Test Report	B-10
None	Subsurface Exploration Summary	B-11

1. INTRODUCTION

1.1 OVERALL PROGRAM

This Manual is one of the elements of a program undertaken by Arthur D. Little, Inc. (ADL) as prime contractor for the Environmental Protection Agency (EPA) under EPA Contract No. 68-02-3167 entitled "Characterization and Environmental Monitoring of Full Scale Utility Waste Disposal Sites". The purpose of this program is to obtain sufficient data and information to enable the promulgation of federal guidelines and regulations under the Resource Conservation and Recovery Act (RCRA) of 1976 for the storage, treatment, and disposal of coal ash (fly ash and bottom ash) and flue gas desulfurization (FGD) waste generated by coal-fired steam-electric generators. The basic objective of RCRA is to insure environmentally acceptable disposal of wastes, one primary element being the prevention of groundwater contamination and the subsequent potential for adverse health and environmental impacts.

Functionally the project has been subdivided into four areas of endeavor:

a The selection of twelve (12) representative utility waste disposal sites. The selection process will take into account:

    1. Waste type (characteristics) and method of disposal;
    2. Geotechnical and hydrogeologic considerations;
    3. Environmental Considerations.

b. The development of the twelve (12) sites for proper environmental monitoring. This effort will consist of the following:

    1. Independent geotechnical and hydrogeologic surveys of each site;
    2. Assessment of the groundwater regimen as it affects waste and host soil sampling-related actions;
    3. Development of groundwater monitoring wells and field support facilities for sampling and analysis.

c. Sampling and analaysis of the waste, groundwater, surface water and the surrounding soils for the purpose of physical and chemical characterization.

d. Engineering/economic assessment of the various types of waste disposal operations, together with the development of adequate cost data describing a generic variety of waste disposal methods.

The result of each of these activities will be subject to a fully integrated environmental assessment as well as engineering and economic analysis, as an aid to EPA in developing appropriate RCRA guidelines.

The project study approach has been divided into three major tasks for obtaining and evluating information at a variety of potential sites:

Task I:	Preliminary Site Selection and Test Plan Preparation.
Task II:	Site Evaluation and Characterization and Environmental Monitoring.
Task III:	Environmental and Economic Assessments.

The principal participates in this overall program are listed in Table 1.

TABLE 1. PRINCIPAL PARTICIPANTS
EPA CONTRACT NO. 68-02-3167

Prime Contractor:	Arthur D. Little, Inc. Cambridge, Massachusetts 02140
Hydrogeologic Subcontractor:	Haley & Aldrich, Inc. Cambridge, Massachusetts 02142
Geotechnical, Field Exploration and Physical Testing Subcontractor:	Bowser-Morner Testing Laboratories, Inc. Dayton, Ohio 45401
Physical Testing QA/QC and Consultants:	University of Louisville Louisville, Kentucky 45208
Chemical Sampling and Analysis Subcontractor:	TRW, Inc. Redondo Beach, California 90278
Engineering and Economic Subcontractor:	Kaiser Engineers/Power Corp. Oakland, California 94623

1.2 PURPOSE

This Manual has been compiled to serve as a Project Hydrogeological and Geotechnical Procedures Manual. The Volume has been designed to provide a common basis for conduct of the Site Evaluation Phase of the contract to characterize and environmentally monitor full-scale utility disposal sites. The prime reason for compiling this Hydrogeologic and Geotechnical Procedures Manual is to insure that project team members conducting field work will do so in a cost-efficient and timely fashion and to establish a similarity of data acquisition, presentation and reproducability across the breadth of the project. Not only must the data be compatible between sites in reliability, but they must be able to stand appropriate scrutiny in the hearings and other actions associated with development of the EPA regulatory process.

This manual is also intended to define the overall philosophy of site development and represents a recurring base of activities and methods to be considered in preparing the specifics of each site evaluation plan.

The technical procedures appended as Exhibits to this Manual are designed primarily to cover the activities of the Project Geotechnical Contractor (Bowser-Morner; B-M) and the Project Hydrogeological Contractor (Haley & Aldrich, Inc.; H&A) during Task I (Preliminary Site Selection and Test Plan Preparation) and Task II (Site Evaluation) of the project.

On designation of a site as a candidate site by the ADL Project Director, personnel from the ADL Site Selection Team will conduct a preliminary site visit to define the extent and character of the waste and disposal operations involved, and the broad environmental, geotechnical and hydrogeological conditions of the site. This preliminary evaluation will determine if the site is such that further consideration for site evaluation is worthwhile. Provided it is so, the ADL Project Director will request personnel from Haley & Aldrich and Bowser-Morner to commence a more detailed site reconnaissance and research of available information. A maximum of eighteen (18) candidate sites may be evaluated by ADL and as many as twelve (12) sites will be subject to detailed analysis by Haley & Aldrich and Bowser-Morner. The site reconnaissance by Haley & Aldrich and Bowser-Morner will lead to preliminary definitiion of the site and on authorization from ADL, these organizations will develop their respective portions of the site specific Test Plan. It is clear that during site reconnaissance and specific Test Plan development, very close coordination of activities between Haley & Aldrich and Bowser-Morner and interfacing with ADL will be required. Furthermore, in cases where Bowser-Morner is not directly involved in drilling, appropriate coordination with organizations supplying drilling rigs will be essential.

At sites where an abundance of data are available on subsurface conditions, the site Test Plan can be prepared to reflect this information, minimizing the amount of additional field verifications required. At these sites, one Bowser-Morner procured or other subcontracted drill rig will be furnished and can be productive until the site evaluation is completed. At many sites, however, it is anticipated that only limited data on field conditions will be available, and at these sites two Bowser-Morner procured or other subcontracted drill rigs may be assigned.

1.3 MANUAL ORGANIZATION

This is one of four basic Manuals that will be produced to maintain a common basis for the conduct of this program and to insure that the project team members conducting various aspects of the field work will do so in an acceptable and cost-effective manner. The project-related subjects for each Manual consist of the following:

Appendix A	Hydrogeologic and Geotechnical Procedures Manual
Appendix B	Sampling and Analysis Procedures Manual
Appendix C	Engineering and Economic Evaluation Manual

This Hydrogeologic and Geotechnical Procedures Manual, Appendix A, provides the basis or overall approach for the following five aspects of site evaluation:

a. Team reasponsibilities and coordination during site evaluation. In particular, this Manual helps establish the interfacing between various subcontractors.

b. Definition of the site evaluation related requirements for test plan development.

c. An overall approach for site evaluation at each site.

d. The use of the site evaluation effort and data collected for assessment.

e. An approach to cost estimating for evaluating each site.

2. TEAM RESPONSIBILITIES AND COORDINATION

2.1 BASIC RESPONSIBILITIES OF TEAM MEMBERS

Hydrogeological and geotechnical activities at the selected sites will encompass three major activities:

a. Hydrogeological professional assignments (H&A) to supervise conduct of hydrogeological investigations and to make appropriate observations and compile field logs and other records of these activities, and to prepare all final geotechnical and hydrological logs and the final site reports.

b. Geotechnical professional assignments (B-M) to supervise conduct of geotechnical investigations and to make appropriate observations and compile field logs and other records of these acivities, and to compile final report submissions as required.

c. Subcontract drilling and field support (B-M or others) in the form of sampling, packaging and shipment of specimens, obtain any necessary test pit excavation equipment, and provision for and conduct of specialized in-situ testing, in support of the geotechnical and hydrogeological investigations.

It is recognized that Bowser-Morner will not be directly providing the equipment and personnel for drilling at all sites. The subcontract for drilling at other sites will be determined by Arthur D. Little in a manner appropriate for that site. In such cases, the exact delineation of Bowser-Morner responsibilities will be established by Arthur D. Little.

During site evaluation, responsibilities will be as follows:

a. Arthur D. Little (ADL), through its Project Director, is responsible for the overall control and management of the project study. Modifications in the Test Plan approach will be authorized or initiated only by the ADL Project Director, as and when required.

b. Arthur D. Little (ADL) is responsible for overall Quality Assurance-Quality Control (QA-QC) activities related to the project study. The following personnel and organizations are responsible for specific project QA-QC requirements:

  - Dr. J.E. Oberholtzer - ADL - Chemical Testing
  - Dr. D.J. Hagerty - U of L - Physical Testing
  - Dr. T.K. Liu - H&A - Hydrogeological Aspects
  - Mr. D.C. Cowherd - B-M - Geotechnical Aspects
  - Mr. H.W. Lambe - ADL - Engineering/Economic Aspects

c. The order to mobilize on a particular site will be given by the ADL Project Director. This authority to initiate activities will go to the Haley & Aldrich Project Manager (in his absence the Haley & Aldrich Project Geologist) and to the Project Geotechnical Engineer at Bowser-Morner, or to his designee.

d. On-site decisions affecting the conduct of the site evaluation activities prior to the arrival of H&A personnel will be the responsibility of the authorized B-M representative.

e. After the arrival of the designated H&A representatives, site decisions will be the responsibility of the H&A hydrogeologist, working in close coordination with B-M and others.

2.2 SEQUENCE OF FIELD ACTIVITIES

The sequence of activities of site evaluation at each site will consist of:

a. Preliminary visit by the ADL site selection team and others;

b. Initial reconnaissance visits by H&A and B-M and others;

c. Development of Test Plans for each site; and

d. Actual site evaluation.

It is noted that the Test Plans for each site will encompass a number of activities besides the exploration activities. The overall responsibility for the Test Plans will rest with Arthur D. Little. Bowser-Morner and Haley & Aldrich will develop information on the site evaluation portion of each Test Plan, subject to overall requirements of ADL. This information will be in the proper format as defined by ADL and will be forwarded to the ADL Project Director. Conduct of site evaluation and other activities at each site will follow the apporach outlined in the Test Plans. Any major variation in the approach affecting site evaluation or its interfacing with sampling and analysis will require appropriate interaction with the sampling and analysis personnel at ADL and/or TRW and be subject to approval by the ADL Project Director.

2.3 COMMUNICATIONS

A preliminary site reconnaissance memorandum, prepared jointly by H&A and B-M, summarizing information obtained and observed during the Task I site visit, will be submitted to the ADL Project Director within one week after completing the preliminary site reconnaissance.

For each disposal facility selected for development, a designated site geotechnical engineer (B-M) and hydrogeologist (H&A) will be responsible for the on-site evaluation. The Project Geotechnical Engineer and Hydrogeologist will be responsible for field sampling and analysis, surveying, well installation drilling and in-situ testing. All activities of B-M and H&A will be fully coordinated for optimal performance in this manner.

Coordination for mobilizing the correct exploration support personnel and equipment, will be the responsbility of the B-M Project Manager, for those sites at which B-M is required to provide this support. Appropriate modifications to this procedure will be made by ADL for other sites. Technical aspects of geotechnical site evaluation activities will be the primary responsibility of the B-M Project Geotechnical Engineer and project hydrogeological activities will be the primary responsibility of the H&A Project Geologist.

Communications from field personnel, during Task II, will be through the H&A Project Manager or Project Geologist (for H&A personnel) and through the B-M Project Geotechnical Engineer (for B-M personnel). In cases in which B-M is not directly involved in the drilling or test pitting, appropriate modifications will be made by the ADL Project Director. The B-M Project Geotechnical Engineer will obtain and coordinate whatever field support requirements are necessary to complete the work outlined in the Test Plans.

The site geotechnical engineer and hydrogeologist will also be responsible for making on-site recommendations as to final location, number, and depth of wells and borings. Any field changes in the Test Plans will be approved by the Project Geotechnical Engineer and/or Project Geologist. Any major changes in the test plans will be approved by the ADL Project Director so that the alterations can be evaluated to determine any effects on sampling and analysis and other aspects of the overall program.

Daily reports, prepared jointly by H&A and B-M field personnel, summarizing production, schedules, subsurface conditions, problems, etc. encountered or observed during the Task II Site Evaluation, will be submitted to their respective project managers at H&A and B-M with copies to ADL. Brief monthly progress reports will be submitted independentally to ADL by B-M and H&A, in summary of total project activities by each firm, for that period.

2.4 COST CONTROL RESPONSIBILITIES

Site evaluation activities will be controlled with a view to maintaining cost optimization for this aspect and for the overall program. Broadly, each of the subcontractors (H&A, B-M, other drilling subcontractors) will be responsible for very close cost control for their particular activities and to maintain their costs within budget. Any anticipated variation in the cost of a site will have to be the subject of discussion between the Site Evaluation subcontractors (H&A and B-M) and an appropriate attempt at optimization and cost control thereof made. If the cost of evaluating a site is likely to be significantly different from that estimated during the preparation of the Test Plan, the ADL Project Director will provide guidance on the optimization effort. The responsibility for exercising appropriate control on Site Evaluation costs will be H&A working in close coordination with B-M, and subject to overall guidance and approval of the ADL Project Director.

2.5 PROJECT REPORT RESPONSIBILITIES

At the completion of a site specific preliminary reconnaissance by H&A and B-M, and submission of their joint trip memorandum to the ADL Project Director, H&A and B-M will prepare their applicable sections of the Task I, Test Plan, upon notification to proceed by the ADL Project Director. The various details, figures, appendices and etc. to be included in this report are outlined in Section 3.0 and are summarized on Table 2 of the Manual.

At the completion of a site specific Site Evaluation by H&A and B-M, a report will be prepared jointly by H&A and B-M of the applicable sections, of the Task II and Task III Final Report. The various details, figures appendices, etc. to be included in this report are outlined in Section 4.0 and are summarized on Table 6 of this Manual.

3. SITE SELECTION AND TEST PLAN PREPARATION (TASK I)

3.1 SITE SELECTION OBJECTIVES

The overall objective of the site selection team is to choose appropriate sites for actual evaluation and environmental monitoring under this program in order to provide guideline criteria for generic-based disposal practices. An important element of site selection is thus the selection of sites where the data gathered can be subject to reasonable assessment later under Task III.

Candidate site selection involves four considerations:

a. The type and characteristics of the FGC wastes and the mode of disposal practices;

b. Geotechnical and hydrogeologic conditions at the site;

c. Environmental conditions at the site;

d. Other factors including utility cooperation.

All attempts will be made to select regional representative sites which are characterized by environmental, hydrogeological and geotechnical conditions which can be adequately analyzed within the cost guidelines of the overall project study.

3.2 SITE REFERENCE MATERIALS

Prior to the commencement of actual site visits, ADL, H&A and others will obtain available site-specific and near-region reference materials of the following types relating to each of the candidate sites:

a. U.S. Geological Survey 1:24,000-scale topographic maps of the area surrounding each site, to a 8 kilometer (5-mile) radius;

b. Where 1:24,000-scale topographic coverage is not available, suitable topographic coverage at a smaller scale will be obtained, to the same radius of coverage;

c. U.S. Geological Survey 1:250,000-scale topographic maps of the area surrounding each site, to a 40 kilometer (25-mile) radius;

d. U.S. or State Geological Survey geologic quadrangle maps of any available scale for the site and area, to a 32 kilometer (20-mile) radius;

e. County soil survey reports of the Soil Conservation Service or its predecessors at the U.S. Department of Agriculture.

f. A variety of federal, state and local governmental agencies, including public and private organizations and individuals, will be contacted for any information which may be applicable to this site evaluation study. These agencies include, but are not limited to the following:

    1. U.S. and State Geological Surveys
    2. U.S. and State Soil Conservation Surveys
    3. U.S. and State Bureau of Mines
    4. National Oceanic and Atmosphere Administration
    5. Corps of Engineers
    6. U.S. and State Environmental Protection Agencies
    7. Tennessee Valley Authority
    8. U.S. and State Bureau of Roads
    9. Specific Utility Authority
    10. Regional and Local Technical Libraries
    11. Local Engineers and Contractors
    12. Local and State Water Surveys

3.3 PRELIMINARY SITE RECONNAISSANCE VISITS

On direction from ADL, personnel from H&A and B-M will visit the candidate sites which appear to offer the best range of site factors. These site reconnaissance visits will be for the purpose of gathering as much geotechnical and hydrogeologic information as possible. Notes and observations collected during these visits will be compiled and recorded in a joint H&A and B-M memorandum to the ADL Project Director. In certain circumstances, ADL may request that additional site area geologic and hydrogeologic information be developed by H&A.

During the site reconnaissance visit, the H&A/B-M representatives will develop preliminary site geotechnical and hydrogeological information from interviews of various utility representatives and a visual examination of the disposal site area. In addition, various state and federal agencies, libraries, drilling firms, local geotechnical firms identified as having worked at or around the plant, and selected municipal officials and libraries, will be visited and interviewed for applicable information. The H&A/B-M site reconnaissance team will obtain 35-mm color slides of the site area conditions for future records and information purposes.

The results and recommendations of the joint H&A/B-M hydrogeological-geotechnical site visit will be presented to the ADL Core Team in both written reports and verbal presentations within one week of the completion of the site visit. Upon Core Team selection of a specific site for Task II evaluation, the ADL Project Director will notify the various participants to commence preparation of a Test Plan draft as outlined on Table 2, Outline for Site Test Plan Format.

Discussions will be held at Core Team briefings for each of the candidate sites that are selected for evaluation. The discussions will result in a mutually agreed-upon, site specific Test Plan that meets the overall objectives of all Core Team members and the purpose of this study. The Test Plan will detail the approximate location, numbers, depths, intervals and other specifications thought to be appropriate to the data needs of the Core Team for that specific site. The Site Test Plan will be a work list of explorations and events and will include regional and local topographic and surficial geology maps and estimated geotechnical and hydrogeologic subsurface condition profiles. The site area topographic map will indicate existing subsurface explorations and observation wells, in addition to indicating the preliminary locations of the study subsurface explorations and observation wells. An accompanying table will be developed which summarizes the completion factors of each borehole, test pit or other related site activity. A budget will be developed as a control measure for this work and will allow the ADL Project Director to govern the general level of effort for each site.

The end result of the site selection process will be the identification of as many as 12 sites for full site evaluation, according to the above-mentioned Task I site specific, Test Plan.

TABLE 2 - OUTLINE FOR SITE TEST FORMAT

1.0 INTRODUCTION (ADL)
  1.1 Project Overview
  1.2 Project Participants
  1.3 Test Plan Organization
  1.4 Objectives

2.0 BACKGROUND
  2.1 Power Plant and Location (ADL & B-M)
  2.2 Waste Type/Disposal Method (ADL & B-M)
  2.3 Geotechnical Baseline (B-M)
  2.4 Hydrogeologic Baseline (H&A)
    2.4.1 Geologic Conditions
      2.4.1.1 Near Region Geology
      2.4.1.2 Site Geology
      2.4.1.3 Estimated General Subsurface Profile
    2.4.2 Hydrogeologic Conditions
      2.4.2.1 Surface Water Regime
      2.4.2.2 Groundwater Regime
      2.4.2.3 Adjacent Groundwater Usage
      2.4.2.4 Evidence of Groundwater Pollution
      2.4.2.5 Climatologic Conditions
  2.5 Other Site Information (ADL)

3.0 SITE EVALUATION PLAN
  3.1 Environmental Issues and Perspective (ADL)
  3.2 Site Evaluation
    3.2.1 Site Development Issues (H&A)
    3.2.2 Drilling Equipment (B-M)
    3.2.3 Geotechnical Evaluation PLan (B-M)
    3.2.4 Hydrogeologic Evaluation Plan (H&A)
    3.2.5 Groundwater Sampling Provisions (H&A)
  3.3 Chemical Sampling and Analysis (ADL, TRW)
  3.4 Physical Testing on Site Analysis (B-M, ADL)
  3.5 Engineering/Economic Data (ADL, KE)
  3.6 Quality Assurance/Quality Control (ADL)

4.0 COST ESTIMATE - ADL with all parties input.

5.0 TENTATIVE SCHEDULE - ADL with all parties input.

6.0 POTENTIAL PROBLEMS - ADL with all parties input.

Illustrations (H&A)

1. Locus Plan
2. Geologic Map of Site (to 5 kilometers (3 mile) radius)
3. Site Evaluation Base Map
4. Generalized Subsurface Profile of Site Area(1)
5. Generalized Subsurface Profile of Site Region(1)
6. Photographs
7. Maps

Notes:
1. Includes both hydrogeological and geotechnical estimates
2. Primary report in writing responsibilities are shown in parentheses (H&A, B-M)

4. SITE EVALUATION (TASK II)

4.1 GENERAL

Subsurface explorations, surficial geological mapping, soil, waste, rock and water sampling from boreholes, groundwater observations, geotechnical laboratory tests and computations make up the site evaluation activities at a given disposal site. These data and findings, together with the reconnaissance findings of Section 3 above, will form the basis for a Final Site Evaluation Report for each of the candidate disposal sites.

Following approval by the ADL Project Director of the site specific Test Plan approach and notice to proceed with the detailed field evaluation aspects of this study, Bowser-Morner will either mobilize their drilling equipment to the site area or sub-contract a local drilling firm for the more remote sites.

Bowser-Morner will commence initial site drilling on the geotechnical explorations and will notify Haley & Aldrich when these explorations will be completed. A H&A geologist will arrive on-site to monitor the hydrogeological explorations and observation well installations for the remainder of the field exploration phase.

The site specific Test Plan will provide the guidance and control for the conduct of the exploration and instrumentation installation program. However, it is anticipated that some deviations in the plan may be required to more thoroughly evaluate the subsurface conditions at a specific site.

The B-M and H&A authorized representatives will discuss and concur on the nature and reasons for deviations from the Test Plan and these requirements will be discussed, via telephone, from the field, with the B-M Project Engineer (in the case of the B-M representative) and the H&A Project Geologist (in the case of the H&A representative). Approval must be granted by one of these individuals at H&A or B-M. If necessary, supporting questins will be asked of the ADL team member responsible for the activity most crucially tied to the question to be resolved. ADL and where appropriate, TRW (depending on job responsibility) will be notified of the change immediately by telephone and subsequently, in writing.

In the event that any changes or deviations in the site specific Test Plan will effect the cost or schedule estimate in the Test Plan, the ADL Project Director will be notified immediately for his approval before initiating any Test Plan modifications.

The basis for decision-making for compilation of the Site Test Plan will be the sample Site Evaluation Models as described in the following sections.

4.2 BORING LOGS

Boring logs will be maintained on the forms that are contained in Exhibit B of this Manual. A single field log will be prepared by the B-M and H&A personnel monitoring the specific drilling rig. Logs will utilize terminology appearing in Exhibit A of this Manual. Field copies of logs will be facsimilie-copied at the site and originals will be mailed or delivered to ADL and H&A in Cambridge and B-M in Dayton. B-M will send the results of physical laboratory testing to H&A for annotation on the logs, prior to preparation of the Final Report, Subsurface Exploration Summary Log for the specific site.

4.3 EXPLORATORY BORINGS IN DISPOSAL WASTE

The purpose of the disposal waste test borings, or geotechnical effort, is threefold as follows:

a. determination of waste deposit boundaries;

b. field testing for determining physical characteristics; and

c. sampling for laboratory testing.

In determining the location of monitoring wells, it is imperative that the boundaries and general composition of the waste be known. The spacing of the test borings will be site-specific, however, a maximum of three (3) to five (5) borings is most probable. The borings should extend to the bottom of the waste pile, and in selected locations, should extend through the waste into the underlying soil liner and/or natural soil horizon. In general, synthetic liners will not be penetrated. The decision to penetrate either natural earth or clay liners will be made by the Core Team at the time of finalization of the site specific Test Plan. In dry fills and in some ponds, it may be advantageous to extend some of the borings deeper and to install observation wells.

In wet pond cases in which penetration of the liner or underlying soil is necessary, the borings shall be installed using driven casing. Such borings within waste deposits which are not scheduled for conversion to observation wells, will be backfilled with concrete or bentonite. Specific details governing the conduct of the field exploration work for all phases, including the installation of observation wells and pieozmeters, is stated in Exhibit A of this Manual, "Specifications for Subsurface Exploration".

A method of evaluating the degree of waste deposit borehole sealing will be recommended, to be applied in the field, before departure of H&A/B-M personnel. The borehole sealing test will be considered as a liability control method. A prime candidate technique for establishing impermeability of the borehole seal will be a falling head permeability test under an evaporation-retarding casing cap. The test should be initiated soon after sealing in order to establish a relatively long period of measurement while H&A personnel are on-site.

The in-situ detemrination of physical properties will be determined in the waste and may be accomplished utilizing standard penetration tests, vane shear tests, and nuclear depth density measurements. In general, such tests will be limited to the waste fill. The standard penetration test will be the most frequently used test because it allows for samples of the waste to be taken in addition to providing correlative information with regard to density and shear strength. Vane shear testing or undisturbed sampling will be performed in selected locations for determining in-place laboratory shear strength parameters. Depth-density readings will provide an accurate determination of in-place density and is hoped to give good depth and age-of-placement relationships that can be used in correlations with field and laboratory permeability data. A correlation between standard penetration resistance, vane shear strength, and in-place density will be made, if possible.

Standard penetration resistance (SPT) tests will be performed on continuous intervals [0.5 meters (1.5 ft.)] for thin waste deposits [less than 3 meters (10 ft.)]; on 0.8 meter (2.5 ft.) intervals for moderate thick waste depsoits [3 to 6 meters (10 to 20 ft.)] and on 1.5 meter (5 ft.) intervals or lesser combinations on thick waste deposits [over 6 meters (20 ft.)]. Stationary piston or Shelby tube samples will be obtained for both physical laboratory and chemical laboratory testing and analysis. It is anticipated that the number of samples obtained will be proportional to the number of varieties of waste materials encountered. As a range, approximately three (3) to six (6) tube samples or more will be obtained for the physical laboratory testing. Additional tube samples will be obtained as required for the chemical testing and analyses. Shelby tube samples will be sealed with microcrystalline, non-shrinking, wax and capped and tapped in preparation for transport. Each sample will be carefully logged with the job number, boring number, depth and sequential sample number. A log of all borings will be prepared and an example of such a log is included in Exhibit B of this Manual. Jar samples will be obtained for each standard penetration test. One (1) jar sample will be sent to B-M and selected jar samples will be sent to either ADL or TRW, depending on the job responsibility.

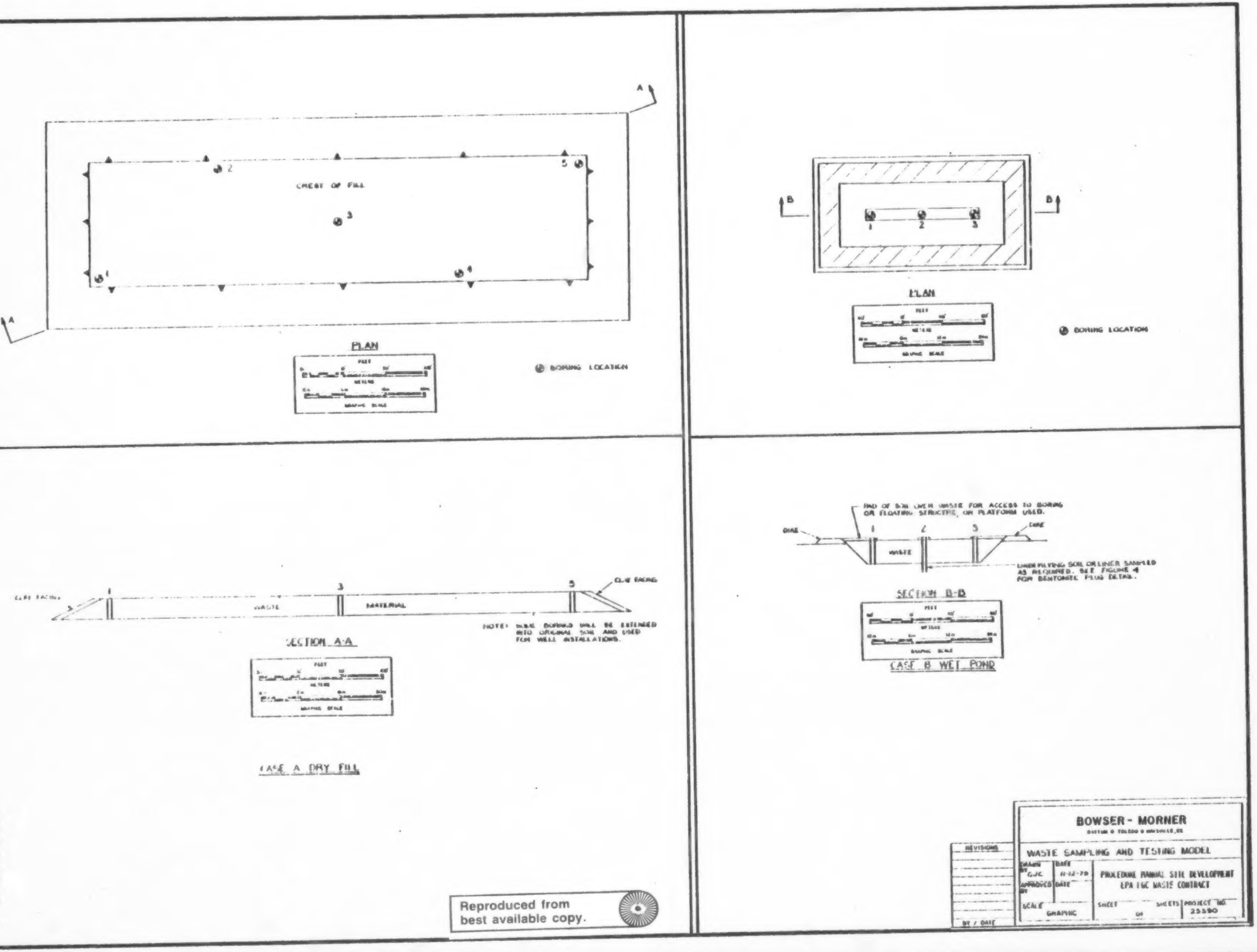
Sampling and analysis of the natural soil strata will be performed in combination with the observation well installations.

For the dry fills, extensive field and laboratory testing is anticipated to determine the effect of increasing density on the waste permeability, shear strength and compressibility. Included in Figure 1 is a model site (dry fill) and the borings to determine the properties of the pile. A list of the types and estimated numbers of laboratory and field analyses to be performed at such a site is included in Table 3.

As previously described, vane shear tests, standard penetration resistance tests, and nuclear depth density test results will be correlated if at all possible. The nuclear depth density tests, if conducted will be performed at .3 to .6 meter (1 to 2 ft.) intervals in one or more of the borings so that an accurate determination of the in-place waste density can be made. The depth density test is performed by installing an aluminum tube in the waste and lowering a probe to the desired depth to determine the density.

Extended laboratory permeability tests will be performed on undisturbed samples so that coefficients of permeability can be determined at various solids contents. Using the nearly continuous depth density measurements, correlations for mass permeability of the entire deposit can be made. Also, compressibility characteristtics of the waste can be determined from the extended permeability tests.

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS


A
A
CREST OF FILL
1
2
3
4
5
PLAN
FEET
METERS
GRAPHIC SCALE
BORING LOCATION
CLAY FACING
1
3
5
WASTE
MATERIAL
CLAY FACING
NOTE: SOME BORINGS WILL BE EXTENDED INTO ORIGINAL SOIL AND USED FOR WELL INSTALLATIONS.
SECTION A-A
CASE A DRY FILL
B
B
1
2
3
PLAN
BORING LOCATION
PAD OF SOIL OVER WASTE FOR ACCESS TO BORING OR FLOATING STRUCTURE, OR PLATFORM USED.
DIKE
DIKE
WASTE
UNDERLYING SOIL OR LINER SAMPLED AS REQUIRED. SEE FIGURE 4 FOR BENTONITE PLUG DETAIL.
SECTION B-B
CASE B WET POND
BOWSER - MORNER
DAYTON • TOLEDO • NASHVILLE, TN
WASTE SAMPLING AND TESTING MODEL
REVISIONS
BY / DATE
DRAWN BY GJC
DATE 11-12-79
APPROVED BY
DATE
PROCEDURE MANUAL SITE DEVELOPMENT
EPA FGC WASTE CONTRACT
SCALE GRAPHIC
SHEET
OF
SHEETS
PROJECT NO. 25590

Reproduced from
best available copy.

FIGURE 1

TABLE 3 APPROXIMATE TESTING ALLOCATION - DRY FILL (1)

Quantity/Site	Item
Laboratory Testing (Number of Tests)	
5	Extended Permeability Tests (Solids Content vs. Permeability)
6	Grain Size Determination
6	Specific Gravity Determinations
20	Moisture Content Determinations
1	Consolidated-Undrained TCTWPPM (4-point envelope)
6	Standard Proctor Tests
Drilling, Field Testing and Sampling	
33 Meters (100 ft.)	Footage of Drilling
20 ea.	Standard Penetration Test or Vane Shear Tests
10 ea.	Shelby Tubes or Stationary Piston Samples
25 ea.	Nuclear Depth-Density Tests (Optional)

(1) To be modified at time of compilation of specific Site Test Plan.

A strength envelope will be determined for the waste material (undisturbed samples) from the consolidated-undrained triaxial compression test with pore pressure measurements. Thus, actual measurement of the engineering properties of shear strength (triaxial compression and vane shear tests), compressibility, and permeability (extended permeability tests) will be available. Index tests (classifications and specific gravity) will be performed on the waste materials to determine whether correlations with measured engineering properties exist.

Standard Proctor compaction tests will be performed to determine the percentage of compaction in the field. This information will be valuable in determining whether additional compactive effort or better moisture content control is effective in increasing field density. If field and laboratory testing indicated that by increasing the waste density, the engineering properties can be improved, then the Proctor data will indicate to what extent the density can be increased.

4.4 EXPLORATORY BORINGS IN DISPOSAL PONDS

Wet ponds are considered to be a more homogeneous depositional mode and not requiring an extensive field and laboratory analyses as the dry fills. A drilling scheme for the pond shown in Figure 1 would include only enough borings to determine the relative dnesity and permeability of the material and to obtain disturbed samples. A list of the types and estimated numbers of lboratory andfield analyses to be performed at such a site is included in Table 4.

TABLE 4 APPROXIMATE TESTING ALLOCATION-WET POND (1)

Quantity/Site	Item
Laboratory Testing (Number of Tests)	
6	Field Permeability Tests
15	Grain Size Analyses
15	Specific Gravity Determinations
40	Moisture Content Determinations
Drilling Field Testing and Sampling	
33 meters (100 ft.)	Footage of Drilling
40 ea.	Standard Penetration Tests or Vane Shear Tests

(1) To be modified at time of compilation of specific Site Test Plan.

4.5 HYDROGEOLOGICAL EXPLORATIONS

It is anticipated that an average of approximately nine (9) hydrogeological borings will be drilled at a site. If there are a significant number of reliable wells already in place, the number may be reduced to an amount sufficient to verify available information. At a minimum, there will be one (1) well up-gradient and three (3) wells down-gradient from each disposal installation. The tentative number of wells will be stated in the site specific Test Plan and the on-site H&A hydrogeologist or Project Geologist will have the responsibility to recommend additional borings based on conditions encountered. Hydrogeological borings will be logged by a representative of H&A. Borings will be logged on forms presented in Exhibit B of this Manual. A control boring will be the deepest exploration and will be continuously sampled or sampled on a more frequent basis than other hydrogeological borings. A background boring will be drilled as close to the hydrogeological up-gradient side of the waste site as possible. At the direction of the site hydrogeologist, it may be necessary to drill additional control or background borings at additional locations in the site area. In general, hydrgeologic borings will not be drilled deeper than 50 feet or to bedrock.

The first hydrogeological pilot boring will determine the basic hydrogeologic requirements and exploration program details for the specific site. Succeeding hydrogeological borings will be developed in the first water-bearing saturated zone below the bottom elevation of the waste site. In the event that more than one saturated unit is present, an attempt will be made to set and seal observation wells or piezometers with a water-quality sampling capability in each unit, to a selected depth to be determined by the H&A Project Geologist. Remaining borings and observation wells will be placed in accordance with the best judgement of the H&A hydrogeologist. If subsequent chemical analyses prove the network to be insufficient to describe conditions at the site, remobilization may be executed, but only at the direction of the ADL Project Director.

Additional hydrogeologic borings will be drilled, one up-gradient of the waste site and the remainder down-gradient. Generally, these borings will be carried to a depth of at least 3 meters (10 feet) below the expected minimum (deepest) seasonal groundwater level. However, in low precipitation "western" sites, this criteria will be adjusted for the site-specific situation. These initial borings and well installations, in the majority of instances, should verfiy the groundwater flow. Standard penetration tests will be performed in each hydrogeological boring in association with sample recovery. Additional hydrogeological borings will be placed as necessary to characterize the groundwater regime. Each completed hydrogeological boring will be flushed or bailed in order to establish hydraulic equilibrium for correct water sampling conditions. Site specific directions will be furnished by the Sampling and Analysis (S&A) team. All borings will be converted to observation wells or piezometers to the extent possible.

Drilling water will come from a single site source, as approved by the S&A team on the basis of water quality samples collected during site selection or site reconnaissance visits.

4.6 PERMEABILITY TESTS

In-situ permeability tests will be conducted below the groundwater table, according to the methods presented in Exhibit A of this Manual. The recovery method, in which no additional water is introduced into the borehole or surrounding soil/rock, is preferred. Since reliable in-situ permeability tests require development of an isolated inflow segment of a particular boring, the use of flush joint, steel casing as the primary borehole stabilization method will allow flexibility during the conduct of the work to perform the most applicable test in the selected horizons for minimum costs. Additional permeability tests will be conducted in the installed observation wells and piezometers. The number of tests for each boring will be a function of the geological conditions encountered during the exploration program.

4.7 IN-SITU CHEMICAL TESTING (SCT)

Chemical index testing (Salinity, Conductivity and Temperature) will be conducted in the control boring and other explorations as appropriate during the field exploration program. The SCT readout unit is a self-contained, portable instrument which has a small diameter probe and can be lowered into a borehole and instantly record the salinity, conductivity and temperature within the borehole. This information will be utilized to detect any variations below the groundwater table from the expected norm which would indicate possible leachate migration. An evaluation of this recorded data may allow better depth selection of observation well points in a particular subsurface horizon.

4.8 VARIATIONS IN SITE MODELS

Several typical site hydrogeologic models are anticipated. These variations will govern the selection of in-hole drilling equipment, the method in which the hydrogeological borings are advanced and the manner in which they are completed and converted to observation wells.

B-M will insure that drilling rigs supplied to the exploration effort are equipped with the indicated equipment, as identified in the activities discussed in Section 4 and Exhibit A of this Manual.

For hydrogeologic purposes, the primary exploration method will require 4-inch diamter, flush-joint, steel casing employing wash boring techniques. The flush joint casing, driven into the overburden materials, will insure proper stabilization and sealing of the upper borehole and facilitate in-situ testing and instrumentation installations. Hollow steam auger boring techniques will be acceptable for investigations in stable soils and well installations that do not have to be isolated from upper strata. The H&A field representative will determine which test boring technique is acceptable for the specific situation that is encountered.

4.9 IDEALIZED SITE EVALUATION SCHEMES

It can not be over emphasized that the geotechnical and geohydrological borings and observation well conversions will be site-specific for each project. Model plans are presented, however, for several simplified site conditions.

Sample well installations and types for six (6) deposit formations are presented as follows:

Case 1	Thin sand deposit
Case 2	Thick sand deposit
Case 3	Two distinct sand layers separated by impervious material
Case 4	Silt or clayey sand deposits
Case 5	Alternating strata of clay and sand
Case 6	Sand and gravel

4.9.1 Thin Sand Deposit

The first model presented is a wet pond installed in a clay deposit which is underlain by a relatively thin [less than 6 meters (20 ft.)] uniform sand deposit which extends to bedrock. The initial borings would be placed in the waste to determine the depth, composition, etc. of the material. The first well installation would be down-gradient approximately 30 meters (100 ft.) from the pond. This boring would be drilled about 15 meters (50 feet) in depth, with continuous sampling and penetration tests. In this manner, any variations in material with depth can be determined at this location. Field permeability tests could also be performed at various intervals for approximate determination of coefficient of permeability, if desired. SCT index tests could be performed at various bottom depths at this location as a double check toward identifying the presence of higher concentrations of leachate.

From the results of the first down-gradient boring, the subsurface conditions at this location could be accurately determined. A slotted PVC pipe would be installed in the boring at this location. The slots would cover a signficiant distance so that leachate from the entire stratum could be monitored.

The next well installation would be up-gradient 30 meters (100 ft.) from the waste deposit and would extend to the same depth as the control boring. The purpose of the intiail two (2) wells would be to verify that the assumed gradient is the actual gradient.

If the actual and assumed gradients are the same then the next well would be installed as close to the waste deposit as possible on the down-gradient side.

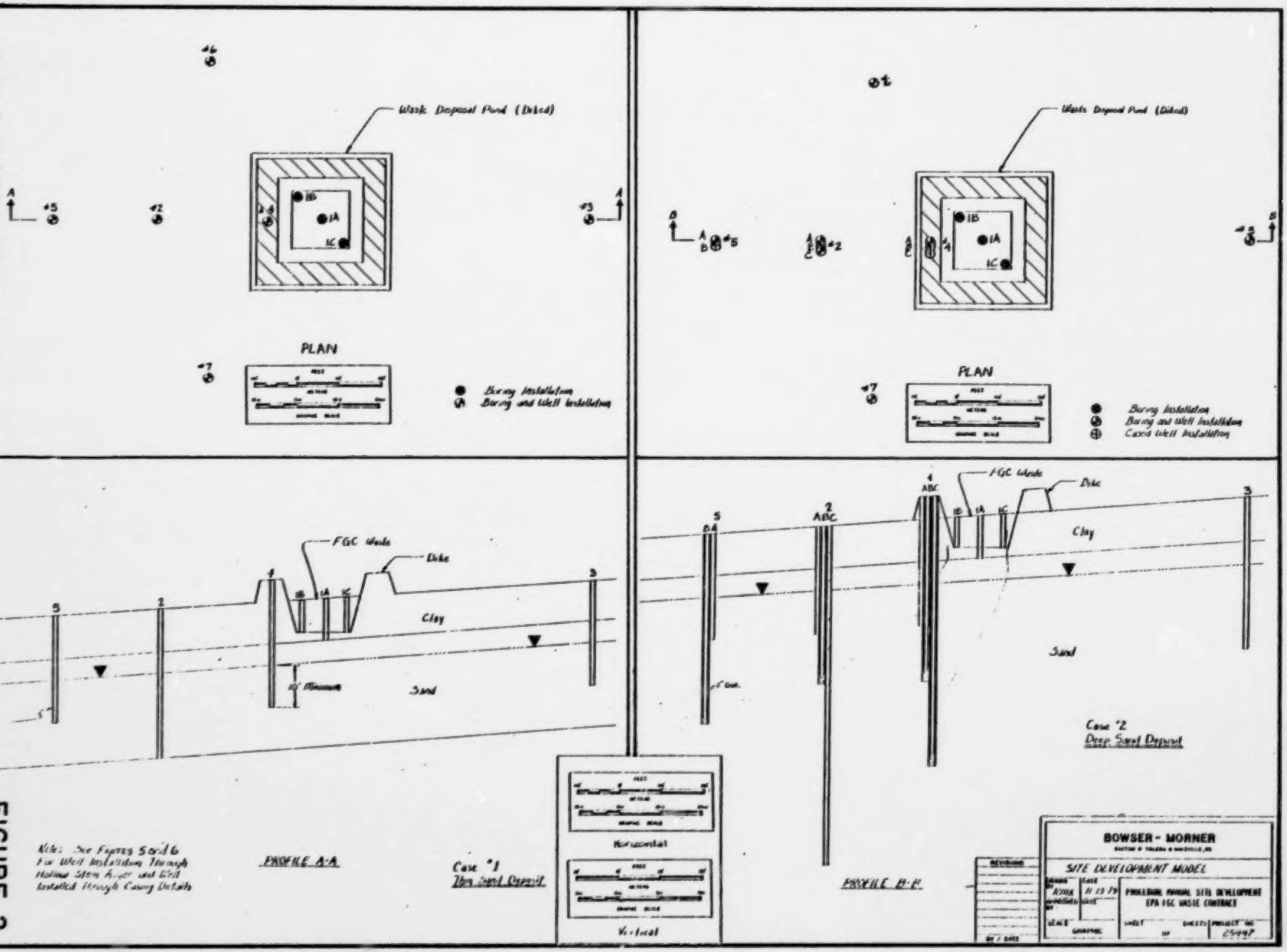
The remaining wells would be installed based on the site specific Test Plan or modified with the ADL Project Director approval on the information obtained from the initial well installations. A sample of the development is shown on Figure 2, Profile A-A.

4.9.2 Thick Sand Deposit

The site evaluation for a thick uniform sand deposit would be similar in design as previously described for the thin sand deposit. The only difference in the thick sand deposit would be the possibility for the leachate plume occurring at a considerable depth in the deposit. Multiple level wells could be installed at various locations or within the same borehole to determine the actual position of the leachate plume. The SCT test performed at the pilot boring location could give an indiciation of the leachate plume position.

Wells isolated at various depth intervals would need to be installed using driven casing such that the upper sand seams could be positively cut off from the lower seams. If the sand deposit is stratified and a simple PVC pipe is dropped through the augers and the sand was allowed to collapse, leachage from the upper portions of the sand deposit could be picked up and transferred to the lower wells. The lower wells would then collect leachate that was not actually occurring in these zones. Bentonite clay seals located above and below the wellpoint will isolate and protect the installation in the desired stratum. Again, additional wells would be installed as determined by the site hydrogeologist.

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS


Waste Disposal Pond (Diked)
PLAN
Boring Installation
Boring and Well Installation
Cased Well Installation
FGC Waste
Dike
Clay
Sand
10' Minimum
PROFILE A-A
Case #1
Thin Sand Deposit
PROFILE B-B
Case #2
Deep Sand Deposit
Horizontal
Vertical
1A
1B
1C
A
B
C
2
3
4
5
6
7
BOWSER - MORNER
SITE DEVELOPMENT MODEL
11 13 79
PROCEDURE MANUAL SITE DEVELOPMENT
EPA FGC WASTE CONTRACT
GRAPHIC
25497

Note: See Figures 5 and 6 For Well Installations Through Hollow Stem Auger and Well Installed Through Casing Details

FIGURE 2

The remaining wells would be installed based on the site specfic Test Plan or modified, with the ADL Project Director's approval, on the information obtained from the initial well installations. A sample of the development is shown on Figure 2, Profile B-B.

4.9.3 Two Distinct Sand Seams Separated by Relatively Impervious Material

The model included in Figure 3, Profile A-A is a wet pond constructed in clay which is underlain by two (2) distinct sand seams separated by relatively impervious clay. The same general procedure for verifying the gradient as previously described would be followed for this location also. Wells installed in the upper sand seam might be installed through hollow stem augers; however, wells installed in the lower sand seam would have to be installed through flush-joint casing. The same sequence of installation would be followed as previously described.

4.9.4 Silt or Clayey Sand Deposits

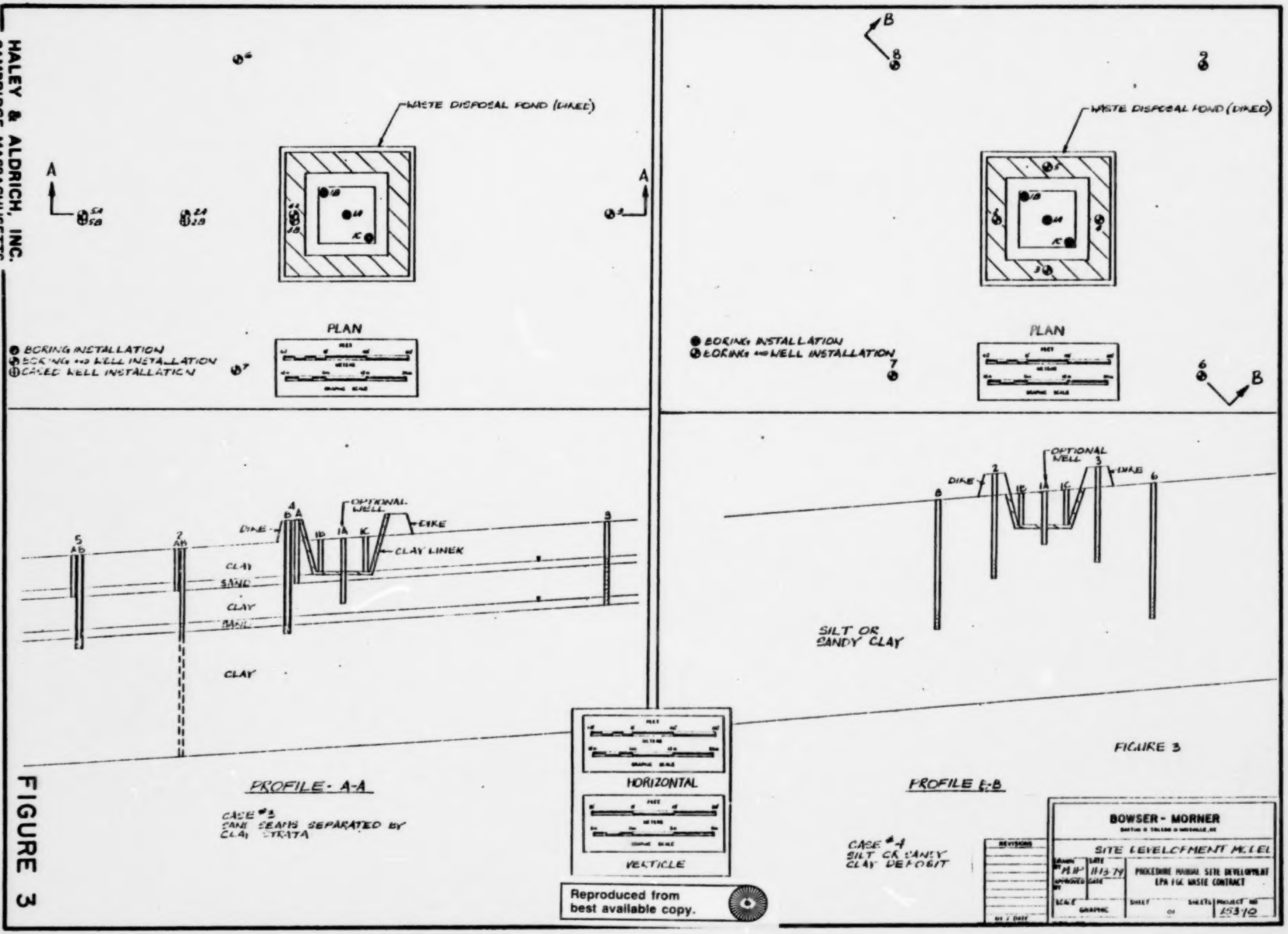
In cases where the groundwater table cannot be readily determined or where determinations of down-gradient is very difficult, the use of piezometers may be utilized on an equal grid pattern around the site as indicated on Figure 3, Profile B-B. It may be possible to install the water observation devices through the use of hollow stem augers; however, if borehole stabilization is critical, flush joint casing will be required.

4.9.5 Alternating Strata, Clay and Sand

In cases were alternating strata occur,it may be advantageous to install separate and isolated wells or piezometers within the same borehole as indicated on Figure 4, Profile A-A. To prevent contamination of adjacent or separate layers, the use of flush joint steel casing will be required so that proper sealing and isolation can be achieved.

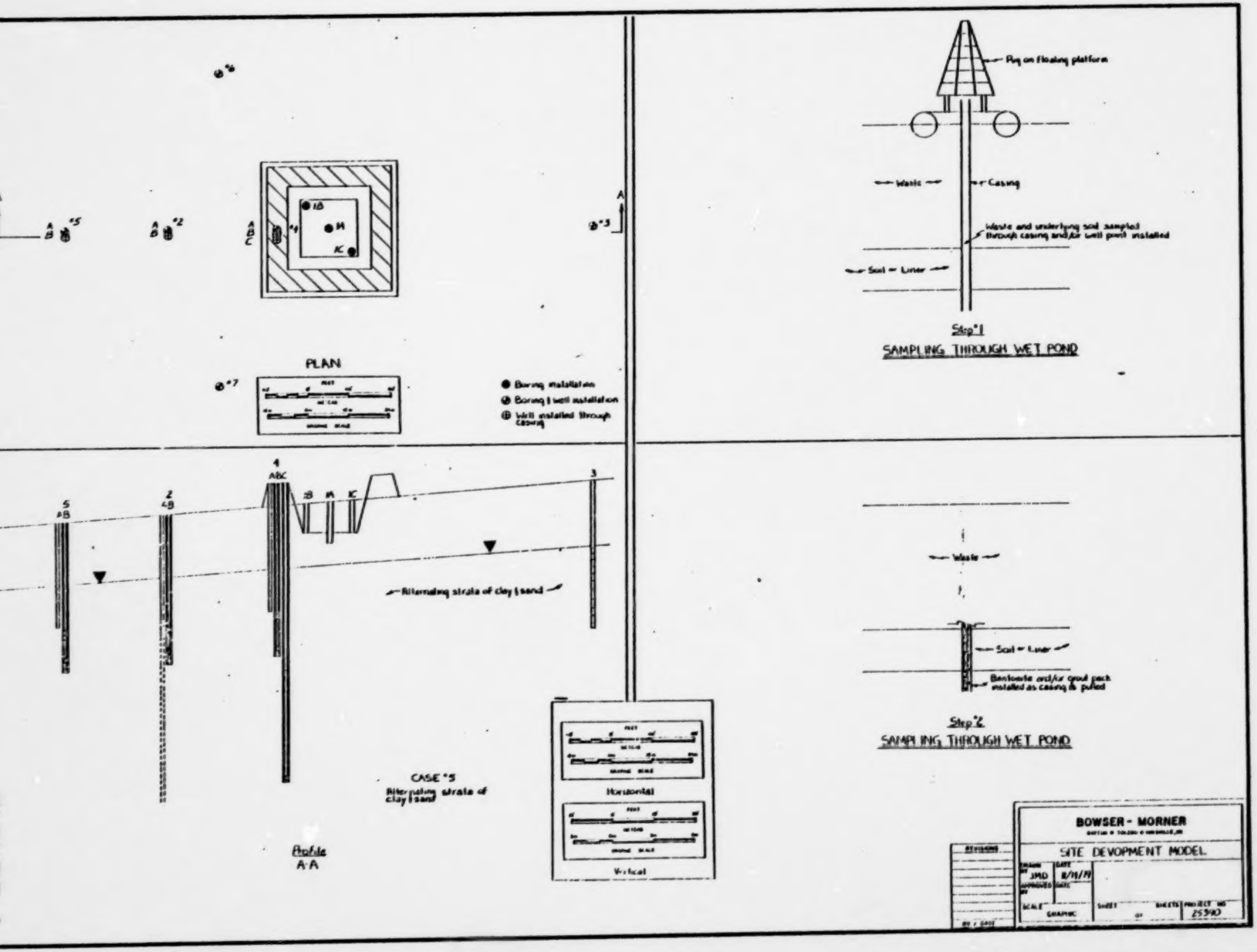
4.9.6 Sand and Gravel

The stabilization of the groundwater will occur very rapidly in these granular deposits. Observation wells may be installed in the averaging or isolated mode, depending on the specific site conditions. Hollow stem augers may be acceptable for installation purposes, but generally these deposits do not retain cohesion below the water table and tend to collapse. Permeability tests in the more granular deposits will require the use of flush joint casing.


WASTE DISPOSAL POND (DIKED)
A
5A
5B
2A
2B
4A
4B
1B
1A
1C
3
6
7
A
PLAN
BORING INSTALLATION
BORING AND WELL INSTALLATION
CASED WELL INSTALLATION
5
A B
2
A B
4
B A
DIKE
1B
1A
1C
OPTIONAL WELL
DIKE
CLAY LINER
CLAY
SAND
CLAY
SAND
CLAY
3
PROFILE - A-A
CASE #3
SAND SEAMS SEPARATED BY
CLAY STRATA
B
8
9
WASTE DISPOSAL POND (DIKED)
5
1B
1A
1C
4
3
PLAN
BORING INSTALLATION
BORING AND WELL INSTALLATION
7
6
B
OPTIONAL WELL
DIKE
8
2
1B
1A
1C
3
DIKE
6
SILT OR
SANDY CLAY
PROFILE B-B
CASE #4
SILT OR SANDY
CLAY DEPOSIT
HORIZONTAL
VERTICLE
FIGURE 3
REVISIONS
BOWSER - MORNER
SITE DEVELOPMENT MODEL
DRAWN BY M.W.
DATE 11-13-79
APPROVED BY
DATE
PROCEDURE MANUAL SITE DEVELOPMENT
EPA FGC WASTE CONTRACT
SCALE GRAPHIC
SHEET OF SHEETS
PROJECT NO 15310

Reproduced from
best available copy.

FIGURE 3



A
A B #5
A B #2
A B C #4
IB
M
K
#3
A
#6
#7
PLAN
● Boring installation
⊘ Boring & well installation
⊕ Well installed through casing
5 AB
2 AB
4 ABC
IB
M
K
3
Alternating strata of clay & sand
CASE #5
Alternating strata of clay & sand
Profile A-A
Horizontal
Vertical
Rig on floating platform
Waste
Casing
Waste and underlying soil sampled through casing and/or well point installed
Soil – Liner
Step #1
SAMPLING THROUGH WET POND
Waste
Soil – Liner
Bentonite and/or grout pack installed as casing is pulled
Step #2
SAMPLING THROUGH WET POND
BOWSER - MORNER
SITE DEVOPMENT MODEL
DRAWN BY JMD
DATE 8/11/79
APPROVED BY
DATE
SCALE GRAPHIC
SHEET OF SHEETS
PROJECT NO 25340
REVISIONS
BY / DATE

FIGURE 4

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

4.10 TYPICAL QUANTITIES FOR SITE EVALUATION

Site specific geologic, topographic and seasonal climatic conditions present a wide variety of reasons which could affect the exploration quantities estimated in the Test Plan which are deemed necessary and which will vary in completion time. For purposes of continuing budgetary control and to present a concept of appropriate level-of-effort, the typical quqntities are presented in Table 5.

TABLE 5 TYPICAL SITE EVALUATION QUANTITIES

All Sites

Two control borings, to be placed in the near position, in the groundwater, down-gradient direction, and one up-gradient at equal distances from the waste deposit, sampled continuously to a depth felt influential to examine the hydrogeologic regime at the site; to be converted at completion into a groundwater obsevation well.

Additional hydrogeological borings, up to an approximate maximum of 9 borings and wells at each site, will be located according to the specific Test Plan guidelines and on-site evaluation of the subsurface conditions as it is obtained.

A series of geotechnical exploration borings in the body of waste; a target number of three such borings were selected; of depths less than 15 meters (50 feet). These borings will generally be drilled and sampled by B-M prior to the arrival of the H&A representative(s). Samples will be of the disturbed and undisturbed variety, collected at standard intervals, except for one boring, designated as the geotechnical control boring, which will be continuously sampled.

Typical Completion Times

A budget figure was developed for carrying all field work through to completion, based on site complexity and climatic conditions:

Low-complexity site:
Three (3) sites considered in this category; requiring one drill rig and one each hydrogeologist and geotechnical engineer; for 14 rig days.

TABLE 5 TYPICAL SITE EVALUATION QUANTITIES (CONT.)

Moderately-complex site with favorable climate:
Two (2) sites considered in this category, requiring one drill rig and one each geotechnical engineer and hydrogeologist; a minimum of 20 rig days.

Moderately-complex site with unfavorable climate:
Three (3) sites considered in this category; requiring one drill rig and one each geotechnical engineer and hydrogeologist; a minimum of 25 rig days.

Complex site with favorable climate:
Two (2) sites considered in this category; one drill rig and one each geotechnical engineer and hydrogeologist; a minimum of 25 rig days.

Complex site with unfavorable climate:
Two (2) sites considered in this category; one drill rig and one each geotechnical engiener and hydrogeologist; a minimum of 30 rig days.

4.11 FIELD EXPLORATION AND TECHNICAL PROCEDURES

Laboratory testing and drilling procedures will be followed according to the ASTM standards where applicable. When no ASTM standards are available, H&A or B-M technical specifications will be used as designated herein. The individual procedures can be found in the following appendices:

Exhibit A: Specifications for Subsurface Exploration

Exhibit B: Field Exploration Forms

4.12 QUALITY CONTROL

Overall quality control for the project will be the responsibility of Arthur D. Little, Inc. Quality assurance will be provided through the use of Haley & Aldrich and Bowser-Morner standard procedures, depending on which team (H&A or B-M) is performing the subject work. The in-house quality control department at B-M will be responsible for equipment calibration and day to day procedure compliance for B-M activities. H&A personnel will adhere to the procedures of this Manual and other applicable H&A quality assurance procedures. Testing equipment and procedures by B-M will be approved by U of L prior to commencing site evaluation and testing. During laboratory analyses, U of L will observe operations and verify results with regard to all physical testing. U of L will perform additional physical tests to verify results obtained by B-M. The various QA-QC personnel for each of the participating organizations is listed in Section 2.1b, pg. 2-1 of this Manual.

4.13 TEST PIT EXCAVATIONS

Machine excavated text pits will be obtained at selected sites at representative locations to obtain more detailed information regarding near surface geological and hydrological conditions. The test pits will also furnish access areas for in-situ testing and bulk sampling requirements.

4.14 ADDITIONAL SITE TASKS

Certain activities, in addition to drilling, logging and in-situ testing, will be necesary to fully characterize each waste disposal site. These activities, and the responsible Core Team member, are as follows:

a. Measure water levels in existing wells and new borings (all parties);

b. Obtain the "as-drilled" location and elevation for all borings and other explorations (B-M);

c. Map site and area geology, including seeps, springs, slips, or other evidence of groundwater discharge (H&A);

d. Describe physical features of water courses at and adjacent to site (H&A);

e. Describe condition of waste sites and coal piles (B-M);

f. Obtain information on other wells or hydrological information within the site area (H&A);

g. Clearly mark all monitor wells and provide for barriers if they seem vulnerable (B-M).

4.15 ADDITIONAL COMMENTS ON SAMPLING AND ANALYSIS

A critical development in site evaluation is appropriate interfacing with the Sampling and Analysis teams. The S&A activities will be conducted as follows:

a. All chemical sampling and analysis will be conducted by ADL and/or TRW. The overall responsibility for quality assurance for chemical sampling and analysis will rest with ADL.

b. Physical and engineering characterization will be done by B-M and the U of L. The U of L will be responsible for Quality Assurance on physical and engineering testing.

The site evaluation subcontractors (U of L, H&A, B-M) will maintain close working relationship with ADL Sampling and Analysis team durng the development of the site specific Test Plan. Furthermore, during later stages of Site Evaluation, an appropriate member of the S&A team, as designated by the ADL Project Director, will be present at the site to insure appropriate interfacing and transition from site evaluation personnel to those of sampling and analysis. It is to be noted that after a site is evaluated, for approximately one year, S&A teams will be visiting the sites to gather groundwater samples, non-point surface water samples, and various other samples for characterization and analysis.

By the same token, during the Site Evaluation phase, personnel from B-M will be collecting waste and soil samples as required. All samples will be labeled by B-M personnel to reflect the following information:

a Site identification number;

b. Boring number;

c. Depth; and

d. Sequential sample number.

An example would be: GN-03-22-13; would indicate that this is the George Neal plant, boring 3, at a depth of 22 meters, and is consecutive sample 13 from boring 3. Chemical analyses samples could also utilize this labeling system.

All on-site water quality sampling will be done by ADL or TRW personnel.

Sampling efforts will take into consideration the fact that single or multiple splits will be made by the Sampling and Analysis team. Adequate quantities must be provided.

Water quality sampling installations in boreholes may be of the multiple-position, single-tube piezometer variety or slotted, PVC casing well points.

As the analysis effort continues, the S&A team will issue a data compilation chart, for each site, showing analytic results for each sampling point. B-M and H&A will review these findings against site-specific knowledge in an effort to provide further relevant interpretations to the Core Team.

4.16 UTILITY INTERFACING

The overall responsibility for Utility Company interfacing on the management level will rest with the ADL Program Director. Once appropriate interfacing and discussions with the Utilities have been completed, ADL will issue appropriate letters of introduction to all field personnel involved in site evaluation and other related activities. These letters can be used by all field personnel to explain the nature of the ongoing work to everyone involved. Constraints, if any in the field activities which must be undertaken by the team members, will be defined by the ADL Project Director.

4.17 USE OF THE METRIC SYSTEM

S.I. system of units will be the primary unit of measurement in all materials appearing in report form. Equivalent English units will be supplied in parentheses.

4.18 FINAL SITE REPORTS

Each site evaluated will be the subject of a final report dealing with geotechnical and hydrogeological aspects of the characterization study. This report will be authored, by section, by B-M and H&A, cross-reviewed, by B-M, H&A & ADL and finalized by H&A. The report draft will be submitted to the ADL Project Director for inclusion in the overall Core Team Final Report.

Table 6, "Final Site Evaluation Report Summary" outlines the various categories of information which will be obtained and reported from all the various phases and sources of site specific information.

TABLE 6 FINAL SITE EVALUATION REPORT SUMMARY

1.0 INTRODUCTION (H&A)

- 1.1 Background
- 1.2 Purpose and Scope
- 1.3 Sequence of Investigation

2.0 SITE DESCRIPTION (B-M)

- 2.1 Location
- 2.2 Nature of Generation Process
- 2.3 Nature of Waste
- 2.4 Type and Configuration of Waste Disposal Site
- 2.5 Site Physiography

3.0 FIELD EXPLORATIONS AND TESTING (H&A and B-M)

- 3.1 General
- 3.2 Geologic Mapping
- 3.3 Subsurface Explorations
- 3.4 Observation Well and Piezometer Installations
- 3.5 Water Sampling Techniques
- 3.6 Field Testing
  - 3.6.1 Permeability
  - 3.6.2 Vane Shear Tests
  - 3.6.3 Nuclear In-Situ Density
  - 3.6.4 Chemical Index Tests

4.0 LABORATORY TESTING OF SOIL AND ROCK (B-M)

- 4.1 General
- 4.2 Classification Tests
- 4.3 Strength Tests
- 4.4 Permeability Tests
- 4.5 Compaction Tests
- 4.6 Chemical Tests
- 4.7 Other Tests

5.0 SITE CONDITIONS AND SUBSURFACE PROFILE (H&A and B-M)

- 5.1 General
- 5.2 Topography
- 5.3 Surface Water and Drainage
- 5.4 Geologic Conditions
- 5.5 Geologic Structure
- 5.6 Waste Site Characterization
- 5.7 Subsurface Profile

6.0 HYDROGEOLOGIC CONDITIONS (H&A)

- 6.1 Hydrogeologic Regime
- 6.2 Flow Gradient
- 6.3 Evidence of Waste/Groundwater Interaction
- 6.4 Climatalogic Conditions

7.0 CONCLUSIONS (H&A and B-M)

REFERENCES CITED (H&A)

TABLES (H&A and B-M)

FIGURES (Minimal coverage is as follows) (H&A)

1. Site Locus
2. Geological Maps (includes hydrogeological and geotechnical features)
3. Subsurface Profiles (includes hydrogeological and geotechnical features)

APPENDICES (B-M and H&A)

- A. Boring Logs
- B. Test Pit Logs
- C. In-Situ Test Data
- D. Laboratory Test Data
- E. Observation Well and Piezometer Readings
- F. Other

EXHIBIT A
SPECIFICATIONS FOR SUBSURFACE EXPLORATION

SECTION I - GENERAL CONDITIONS

1.01 General. These specifications establish administrative and technical procedures for conducting field investigations relating to U.S. Environmental Protection Agency (EPA) Contract 68-02-3167, Characterization and Environmental Monitoring of Full Scale Utility Waste Disposal Sites. The specifications supplement the Generic Site Evaluation Plan for Hydrogeological and Geotechnical Site Development Activities, issued as the governing document.

1.02 Participating Parties. The following organizations are considered to be key participants in the Hydrogeological and Geotechnical aspects of the projects:

Arthur D. Little Inc. (ADL) - Project Management;
University of Louisville (U of L) - Project Consultants and Quality Control for Physical Testing;
Haley & Aldrich Inc. (H&A) - Project Hydrogeology;
Bowser-Morner Testing Laboratories, Inc. (B-M) - Project Geotechnical Engineering, Field Explorations, and Field and Laboratory Testing.

1.03 Definitions.

Contractor shall mean Bowser-Morner Testing Laboratories, Inc. (B-M) or other subcontractor for field exploration equipment and services, such as drilling and test-pitting.

Hydrogeologist shall mean the authorized H&A representative assigned to perform site-related observations.

Geotechnical Engineer shall refer to the authorized B-M representative assigned to perform site-related observations and to supervise the condut of B-M subcontracted drilling and other field exploration equipment support activities.

The term Work is used to designate all field personnel assignment, services, equipment, materials and other activities required to be furnished or performed by each Contractor, as described in the Specifications and Plans attached hereto and made a part hereof.

Overburden refers to all unconsolidated materials lying above sound bedrock, to include natural soils, residual soils, fill, waste and boulders.

Bedrock means all siltstone, shale, slate, sandstone, limestone, granite, and all other naturally cemented or consolidated geologic materials for which diamond core drilling is necessary to obtain samples.

1.04 The General Work Agreement The Contractor shall furnish all labor, materials, equipment, tools, supplies, and other facilities, and shall perform all work necessary or proper and shall bear all expenses for or incidental to the making of the subsurface explorations at the locations shown on the plans. This work shall be performed in accordance with the Specifications bound herewith and the accompanying Plans and to the satisfaction and approval of the Project Manager. The Contractor shall perform all obligations and assume all liability and assume all expenses imposed upon him by the Contract.

1.05 Personnel, Equipment, Commencement and Methods

1.05.1 Qualified Personnel

The Contractor specifically warrants that his firm and particularly those persons to be employed in the performance of the work are qualified by experience and training and are thoroughly competent to perform the duties required herein and that those in responsible charge of the test boring operations have carefully examined the contract documents and shall diligently fulfill all requirements.

1.05.2 Plant and Equipment

The Contractor also warrants that all plant facilities and equipment as required in the exploration, investigation, and testing shall be of recent manufacture, in first-class working order, in proper adjustment for the precision required, and shall conform to the highest professional standards for the specific task involved. All equipment shall be approved by the Project Manager or his authorized representative and shall not be changed, or varied, unless by the written consent of the Project Manager.

1.05.3 Commence Work

The Contractor agrees forthwith to mobilize his personnel and equipment as set forth in 1.03.1 and 1.03.2, respectively, and to commence productive work at the site within five (5) consecutive calendar days from the date of the Notice to Proceed for this Contract.

1.05.4 Methods, Recording

All investigation methods and procedures, logs and data gathering and recording techniques, data, and plan preparation shall be approved by the Project Manager or his authorized representative and shall not be changed, or varied, unless by the written concent of the Project Manager.

1.06 Payment Upon the satisfactory completion of all work whatsoever required, the Geotechnical Engineer will determine the amount of work performed and the compensation earned by the Contractor and will give notification thereof to the Contractor. The Contractor shall thereupon furnish to the Geotechnical Engineer satisfactory evidence that all just liens, claims and demands of sub-contractors, laborers, and material suppliers, arising out of the work, are fully satisfied and that all of the work is fully released from all liens, claims or demands whether just or otherwise. Upon receipt of such satisfactory evidence, the Geotechnical Engineer will submit to the Project Manager a statement of the value of the completed work.

Upon completion of all phases of the work, the acceptance by the Contractor of the Final Payment shall stand as a release of all participating parties for all the claims and liability of the Contractor relating to or arising out of the work, or provisions of the Contract.

1.07 Execution and Completion of Work

1.07.1 Requirements

The following equipment and crews will constitute the minimum requirement during the exploration program under this Contract: one (1) complete drill rig and crew per site for the duration of the field exploration program.

1.07.2 Permits

The Contractor shall apply for and procure all necessary permits, special insurance and licenses, pay all charges and fees and give all notices necessary and due in connection with the lawful prosecution of the work.

The Contractor shall be solely responsible for any and all damage to public and private utilities incurred during his performance of the work under this contract.

The Contractor shall, at his own expense, secure and pay to the appropriate State or County organization or municipality, the fees or other charges for all permits for water, sidewalk crossings, shed erection, removal of abandoned water taps, sealing house connection drains, pavement cuts, and repaving of streets and sidewalks and all other building, electrical, plumbing, gas and sewer permits required for the performance of the work by the cognizant regulatory bodies or any of their agencies.

The Contractor shall comply with applicable laws and ordinances governing the disposal of materials, debris, rubbish and trash generated in the performance of the work whether on or off the project.

1.07.3 Barricades and Warning Signs

The Contractor shall, at his own expense, provide, place and erect all necessary barricades and warning signs and furnish and keep lighted all lights necessary and required to protect the work from traffic, pedestrians and animals.

1.07.4 Public Convenience and Safety

The Contractor shall be responsible for maintaining the flow of traffic over, through, and around the work included in his contract with the maximum of safety and convenience to the traffic during the life of this contract. Such responsibility shall continue whether or not work thereon has been temporarily suspended. The Contractor shall take all precautions for preventing injuries to persons or damage to property in or about the work. The work shall be executed in such manner so as to provide convenience, safe passage and least obstruction to public travel at all times.

Streets or access roads shall be closed to travel only as directed by the Geotechnical Engineer or as permitted by local civil authority or plant management. The Contractor shall, at all times, conduct the work so that the abutters to existing public ways shall have reasonable access.

When it is necessary to leave material or equipment on the public ways, it shall be placed so as to cause the least possible obstruction to pedestrians and vehicular travel.

The Contractor shall make application and pay the fees for all street, sidewalk, and other permits as required and shall coordinate such application and issuance with the work requirements so as not to cause any delay of this contract.

The Contractor shall remove and properly dispose of all debris, rubbish, and excess materials as the work progresses. The work site, equipment and materials used by the Contractor shall be kept in a neat and orderly manner. At the termination of this Contract, the Contractor shall remove any remaining equipment, materials or debris and restore the site to reasonable condition or to condition existing prior to start of work.

1.07.5 Protection of Property

The Contractor shall, at his expense, preserve and protect from damage all property whether public or private adjacent to the work, and he shall assume the responsibility and expense for all damage and injury arising out of or related to any act or omission of the Contractor or his employees or subcontractors in the performance of the work.

The Contractor shall exercise special care during his operations to avoid injury to underground structures, such as water or gas mains, pipes, conduits, manholes, catch basins, hydrants, steam main, telephone lines, etc. The Contractor shall notify and cooperate with representatives of public service companies in order to protect their structures from damage. Fire hydrants adjacent to the work at all times shall be maintained readily accessible for fire protection.

1.08 Liability and Responsibility of Contractor The Contractor shall, to the full extent permitted by applicable law, indemnify, hold harmless and, upon the Project Manager's request, defend the Project Manager, the Hydrogeologist, and the Geotechnical Engineer, and their respective officers, employees, agents and representatives against any and all claims, losses, costs and damages based upon injury to or death of any person or damage to or loss of any property arising out of or resulting directly or indirectly from the negligent acts, errors, or omissions of the Contractor or its employees, subcontractors or agents in the performance of the work and/or failure to comply with the terms and conditions of this contract.

The Contractor shall be responsible for payment of all services, labor, equipment and materials furnished by or through him for the purposes of the Contract. The Contractor shall indemnify and protect the Project Manager, the Hydrogeologist and the Geotechnical Engineer from all claims from mechanics, laborers, subcontractors, material suppliers and others, for services or labor performed, materials or equipment furnished and used. If through neglect of this provision, or other, by the Contractor, claims against the Contractor are filed with the Project Manager, it is agreed by the Contractor that until such claims have been discharged or secured satisfactorily, the Project Manager may retain from money due the Contractor an amount sufficient in the opinion of the Project Manager to cover said claims including expenses made by the Project Manager for the investigation and defence of said claims.

The Contractor shall be responsible for the professional quality, technical accuracy and the coordination of all work performed by the Contractor under this contract. The Contractor shall, without additional compensation, correct or revise any errors or deficiencies in his work product.

Neither the review, approval or acceptance of, nor payment for, any of the work by the Project Manager, the Hydrogeologist or the Geotechnical Engineer shall be construed to operate as a waiver of any rights under this contract or of any cause of action arising out of the performance of this contract and the Contractor shall be and remain liabile to the Project Manager, the Hydrogeologist, and the Geotechnical Engineer in accordance with applicable law for all damages caused by the Contractor's act, error, omission or negligence in the performance of any of the work.

1.09 Equal Employment Opportunity In connection with the execution of this contract, the Contractor shall not discriminate against any employee or applicant for employment bdcause of race, religion, color, sex, or national origin. The Contractor shall take affirmative actions to insure that applicants are employed and that employees are treated during their employment, without regard to their race, religion, color, sex, or national origin. Such actions shall include, but not be limited to, the following: employment, upgrading, demotion or transfer, recruitment, or recruitment advertising, layoff or termination, rates of pay or other forms of compensation and selection for training, including apprenticeship.

1.10 Subcontractors The Contractor, in the performance of all work after award and prior to completion of the contract work, shall not discriminate on grounds of race, religion, color, sex, or national origin, in the selection or retention of subcontractors, and in the procurement of materials and rentals of equipment.

1.11 Clean Air Act of 1976 Work performed by the Contractor shall be in compliance with the provisions of the Clean Air Act of 1976, 42 USCS, Sections 1857-1857F.

1.12 Boring Foreman. The Contractor shall employ at all times during the progress of work at the site a competent boring foreman and assistants, as may be necessary, all of whom shall be satisfactory to the site Geotechnical Engineer and the Site Hydrogeologist. The boring foreman shall not be changed except with the consent of the Geotechnical Engineer. The boring foreman shall represent the Contractor in his absence and all directions given to him shall be as binding as if given to the Contractor himself. Verbal directions shall be confirmed in writing on request in any case.

1.13 Inspection of work. All test borings, sampling, field testing, groundwater observation wells, and other work under this Contract, will be inspected in the field by a qualified hydrogeologist or geotechnical engineer representing the Project Manager. No work shall be performed under this Contract unless the inspector is present at the work site. The Project Manager, the Hydrogeologist, and the Geotechnical Engineer, and their representatives, shall at all times have access to the work. The making of borings, the performance of tests, the taking of samples, installations of observation wells, the recording of samples, and the storing and disposal of samples shall be in accordance with the requirements of these Specifications and the directions of the Geotechnical Engineer or the Hydrogeologist and will be continually inspected by their representatives.

1.14 Locations. The number, type and location of the borings, field tests and observation wells shall generally be as indicated on the plans or as directed by the Geotechnical Engineer or the Hydrogeologist.

The "as-drilled" locations of all explorations including test borings, test pits, observation wells and any supplemental explorations will be determined by the Geotechnical Engineer. Such locations shall be within 30 cm. (one (1) ft.) horizontally and 3 cm. (one-tenth (0.1) ft.) vertically and referenced to the required project datum.

1.15 Authority of the Hydrogeologist and the Geotechnical Engineer All work shall be performed to the satisfaction of the Geotechnical Engineer and the Hydrogeologist and at such times and placed, by such methods and in such manner and reasonable sequence as he may require; and the work shall at all stages be subject to their inspection. The Geotechnical Engineer and the Hydrogeologist will determine the amount, quality, acceptability, and fitness of all parts of the work, will interpret the Plans and Specifications, and will decide all other relevant questions.

In the performance of the work, the Contractor shall conform to all orders, directions, and requirements of the Geotechnical Engineer and the Hydrogeologist. He shall employ no plant, equipment, materials, methods, or men to which the Geotechnical Engineer or the Hydrogeologist objects, and shall remove no plant, equipment, or other facilities from the site of the work without permission of the Geotechnical Engineer.

1.16 All Laws and Regulations The Contractor shall comply with all applicable provisions of any Federal, State, County, Municipal, Local, and Departmental Laws, ordinances, rules, regulations, orders, permits, and licenses which affect the work and those engaged therein.

1.17 Insurance

1.17.1 The Contractor shall carry comprehensive general liability insurance with limits not less than $1,000,000 per occurrence for bodily injury and $200,000 per occurrence for property damage and automobile liability insurance with limits not less than $500,000 per person and $1,000,000 per occurrence for bodily injury and $500,000 per occurrence for property damage covering all work performed under this contract. Such insurance shall include the following:

A. All operations, including the use of all vehicles.

B. Contractual liability covering this contract.

C. "Personal" injury (in lieu of, or in addition to, "Bodily" injury).

1.17.2 The Contractor shall carry workmen's compensation insurance, including employer's liability insurance, as required by the State in which the work is being conducted, covering all work performed by Contractor under this contract.

1.17.3 Insurance similar to that required of the Contractor shall be required of any subcontractors to cover their operations performed under this contract. The Contractor shall be held responsible for any modifications in these insurance requirements as they apply to subcontractors unless such modifications have the Project Manager's approval. Individual consultants shall not be considered subcontractors for purposes of this section.

1.17.4 Project Manager (ADL), the Hydrogeologist (H&A) and the Geotechnical Engineer (B-M), shall be named as additional insured under the insurance maintained by Contractor pursuant to Section 1.17.1.

1.17.5 Insurance certificates evidencing the above are to be furnished to the Project Manager and shall provide not less than ten (10) days' prior notice to the Project Manager of any cancellation modification or change in the policies.

1.18 Accidents. The Contractor shall provide at the site such first-aid equipment and medical facilities as are necessary for treatment to personnel who may become injured in connection with the work. The Contractor shall promptly report in writing to the Project Manager all job-connected accidents causing death, personal injury, or property damage, giving full details and statements of witnesses. In the case of death, serious injury, or serious damage, the accident shall be reported immediately be telephone or messenger to the Project Manager. If any claim is made by anyone against the Project Manager, the Hydrogeologist, or the Geotechnical Engineer, the Contractor shall promptly report the facts in writing to the Project Manager, including full details of the claim.

1.19 Ownership of Data No information concerning the work or the results thereof is to be released by the Contractor to any other person or agency other than the ADL Project Director, the Hydrogeologist, or the Geotechnical Engineer, except after prior approval of the ADL Project Director, or as necessary for the performance of the work. All press releases, including information to be published in newspapers, magazines, etc., are to be handled only through the ADL Project Director.

1.20 Miscellaneous The Contractor warrants that he has not employed or retained any company or person, other than a bona fide employee working solely for the Contractor, to solicit or secure this contract and that he has not paid or agreed to pay any company or person, other than a bona fide employee working solely for the Contractor, any fee, commission, percentage, brokerage fee, gifts or any other consideration, contingent upon or resulting from the award or making of this contract. For breach or violation of this warranty, the Project Manager shall have the right to annul this contract without liability.

SECTION II - TECHNICAL PROVISIONS

2.01 Conduct of the Work In order to obtain reliable information on subsurface conditions, the Contractor shall conduct the work so as to give the Geotechnical Engineer and the Hydrogeologist every facility to obtain his own record including groundwater level, classification of sample material, driving records on casing and sample tubes, notations of every detail of the work, and to obtain an accurate record of the soil profile disclosed by the exploration operation.

The Contractor shall notify tbe Project Manager of his intention to start exploration operations at least five (5) days in advance of the start of the work, or of his intention to add extra rigs and crews on any part of the project.

The Contractor shall provide and must maintain the equipment and drilling crew (s) at each site of work in order to complete the Contract entirely within the approved time schedules. If, in the opinion of the Geotechnical Engineer or the Hydrogeologist, the plant and equipment mobilized are inadequate to complete the work within the time allowed, the Contractor, upon direction of the Geotechnical Engineer, shall employ such additional number of crews, rigs, equipment, and work shifts as may be necessary to meet the schedule.

No exploration shall be done before sunrise or after sunset except with the written approval of the Geotechnical Engineer. Approval for night work may be granted if the Geotechnical Engineer can be assured that it is necessary and feasible, adequate lighting is provided, and the exploration operations will conform to this Specification.

2.02 Borings

2.02.1 General Each boring shall be advanced without change in crew from commencement to approved completion, except when such change is approved by the Geotechnical Engineer.

2.02.2 Type Borings shall be selected as necessary to take split-spoon samples, core bedrock, obtain undisturbed stationary piston samples, Shelby tube samples, install observation wells, piezometers and perform field vane shear and other tests as determined by the Geotechnical Engineer and the Hydrogeologist.

2.02.3 Number, Location and Estimated Depth The approximate number and location of the test borings required are shown on the contract plans. The estimated depths of these explorations are summarized in Table I. The actual number, location and type of exploration including depths, samples, in-situ tests, etc., will be determined by the

Geotechnical Engineer and the Hydrogeologist during the conduct of the field investigation program. (ADL NOTE: Table I, summarizing estimated detphs, samples, tests, etc. will be prepared subsequent to the preliminary reconnaissance visits of the various sites and prior to actual field drilling.)

2.03 Boring Installation

2.03.1 General The sequence of borings and the tests to be performed, the type or types of samples to be taken at each hole, and the observation wells and piezometers to be installed, are shown on the Contract plans or as directed by the Geotechnical Engineer, and the Hydrogeologist, and are summarized in Table I.

2.03.2 Drilling Method The subsurface explorations will utilize both flush joint, steel-casing boring methods and hollow-stem auger boring methods.

2.03.3 Drilling Water The use of clean, fresh water will be required from a single source, if required for borehole advancement, and conduct of infiltration-type permeability tests.

The use of sewage effluent, acid mine water, or saline or brackish water will not be allowed.

2.03.4 Flight Augers The use of continuous hollow-stem flight augers will be selectively allowed only with the express approval of the Geotechnical Engineer and the Hydrogeologist during the conduct of the work.

2.03.5 Uncased Holes Drilling methods employing uncased holes may be employed only with the specific approval of the Geotechnial Engineer and the Hydrogeologist. In such borings, casings shall be driven to such depth below the surface of the ground as required to maintain the sides of the borehole.

2.03.6 Casing Casing shall be driven vertically through earth or other materials to such depth below the surface of the ground as required to maintain the sides of bore holes or as directed by the Geotechnical Engineer and the Hydrogeologist. Simultaneous washing and driving of the casing will not be permitted except by order of the Geotechnical Engineer and the Hydrogeologist and where so permitted, the elevations between which water was used in driving the casing must be recorded. When sampling in sands and loose silts, the Contractor will be required to keep the casing full of water at all times. If this measure is insufficient to prevent the material from running up into the casing due to artesian water conditions, the Contractor will be required to use commercial biodegradable drilling mud. The number of blows per foot required to drive the casing shall be recorded.

2.03.7 Casing Size Casing shall be at least 101.6 mm. (4 inch) I.D., HW or HX flush joint, steel casing for explorations that require observation well and piezometer installations, vane shear testing and stationary, undisturbed piston sampling. Explorations that are to be conducted for waste sampling or do not require in-situ testing or observation well installations may utilize 63.5 mm. (2.5 inch) I.D., BW or BX flush joint, steel casing or hollow stem augers.

2.03.8 Removal of Casing The casing shall be removed upon completion of the work, and it shall remain the property of the Contractor. However, no casing shall be removed until measurement of the groundwater level has been made and recorded and the Hydrogeologist has approved casing removal.

2.04 Soil Classification System The project soil classification system utilizes a slightly modified version of the Unified Soil Classification System where descriptive terms have been substituted for letter designations. The standard USCS group symbol identification will also be required for each of the various strata encountered (Figure A).

2.04.1 Color. When the color of the soil is uniform throughout, it will be recorded such as brown, gray, black, and may be modified by adjectives such as light or dark. If the predominant soil color is shaded by a secondary color, the secondary color precedes the primary color such as gray-brown, yellow-brown. If two major and distinct colors are swirled or mottled throughout the soil, the colors will be modified by the term mottled, such as: mottled brown and gray.

2.04.2 Grain Size.

Material	Definition	Fractions	Sieve Limit	
			Upper	Lower
Boulders	Material too large to pass through an opening 200 mm. (8 in.) square			
Cobbles	Material passing through a 200 mm. (8 in.) square opening and retained on the 76 mm. (3 in.) sieve			
Gravel	Material passing the 76 mm. (3 in.) sieve and retained on the No. 4 sieve	Coarse	76 mm. (3 in.)	20 mm. (3/4 in.)
		Fine	20 mm.. (3/4 in.)	No. 4

UNIFIED SOIL CLASSIFICATION SYSTEM

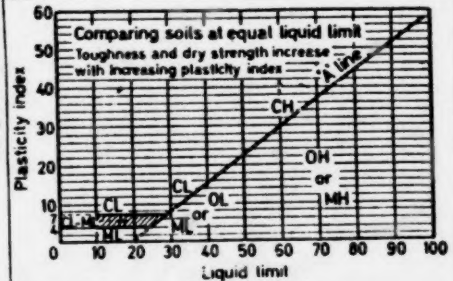
Field identification procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)						*Group symbols* 1	*Typical names*	*Information required for describing soils*	*Laboratory classification criteria*			
Coarse grained soils *More than half of material is larger than No. 200 sieve size* 1 (The No. 200 sieve size is about the smallest particle visible to naked eye)	*Gravels* *More than half of coarse fraction is larger than No. 4 sieve size* (*For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size*)	*Clean gravels (little or no fines)*	Wide range in grain size and substantial amounts of all intermediate particle sizes			*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics *Example*: *Silty sand*, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	Use grain size curve in identifying the fractions as given under field identification	Determine percentages of gravel and sand from grain size curve Depending on percentage of fines (fraction smaller than *No. 200* sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP* More than 12% *GM, GC, SM, SC* 5% to 12% *Borderline* cases requiring use of dual symbols	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing			*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines				Not meeting all gradation requirements for *GW*	
		Gravels with fines (appreciable amount of fines)	Non-plastic fines (for identification procedures see *ML* below)			*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures				Atterberg limits below 'A' line, or *PI* less than 4	Above 'A' line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)			*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures				Atterberg limits above 'A' line, with *PI* greater than 7	
	Sands *More than half of coarse fraction is smaller than No. 4 sieve size*	*Clean sands (little or no fines)*	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			*SW*	Well graded sands, gravelly sands, little or no fines				$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing			*SP*	Poorly graded sands, gravelly sands, little or no fines				Not meeting all gradation requirements for *SW*	
		Sands with fines (appreciable amount of fines)	Non-plastic fines (for identification procedures, see *ML* below)			*SM*	Silty sands, poorly graded sand-silt mixtures				Atterberg limits below 'A' line or *PI* less than 4	Above 'A' line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)			*SC*	Clayey sands, poorly graded sand-clay mixtures				Atterberg limits shows 'A' line with *PI* greater than 7	
Fine grained soils *More than half of material is smaller than No. 200 sieve size*	*Identification procedures on fraction smaller than No. 40 sieve size*											
			Dry strength (crushing characteristics)	*Dilatancy (reaction to shaking)*	*Toughness (consistency near plastic limit)*							
	Silts and clays liquid limit less than 50		None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions *Example*: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)		 Plasticity chart for laboratory classification of fine grained soils		
			Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays					
			Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity					
	Silts and clays liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or dictomaceous fine sandy or silty soils, elastic silts					
			High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays					
			Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity					
Highly organic soils			Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils					

Figure A

Material	Definition	Fractions	Sieve Limit Upper	 Lower
Sand	Material passing the No. 4 sieve and retained on the No. 200 sieve	Coarse Medium Fine	No. 4 No. 10 No. 40	No. 10 No. 40 No. 200
Silt	Material passing the No. 200 sieve which is also non-plastic in character and exhibits little or no strength when dried.		No. 200	
Clay	Material passing the No. 200 sieve which can also be made to exhibit plasticity within a certain range of moisture contents and which exhibits considerable strength when air dried.		No. 200	

2.04.3 Relative Compactness

Degree of Compactness	Standard Penetration Blows per Foot (30 cm.)
Very loose	5 or less
Loose	6 to 10
Medium dense	11 to 30
Dense	31 to 50
Very dense	51 or more

2.04.4 Relative Consistency

Relative Consistency	Standard Penetration Blows per Foot (30 cm.)
Very soft	3 or less
Soft	4 to 5
Medium stiff	6 to 10
Stiff	11 to 15
Very stiff	16 to 30
Hard	31 or more

2.04.5 Relative Moisture

Term	Relative Moisture
Dry	Powdery
Damp	Moisture content below plastic limit
Moist	Moisture content above plastic limit but below liquid limit
Wet	Moisture content above liquid limit

2.04.6 Description

Major soil component = Upper case letters

Secondary component = Adjective used (if 20-50 percent of total)

Third component = "Some" used (if third component comprises 20-35 percent of total)

Other components = "little" used (if 10-20 percent of total)

= "trace" used (if less than 10 percent of total)

Examples = Gravelly coarse to fine SAND, little silt, trace clay

= Silty medium to fine SAND, some gravel, little clay, trace coarse sand and cobbles - GLACIAL TILL -

2.05 Split-Spoon Sampling

2.05.1 Sampling Split-spoon drive samples shall be obtained at the beginning of every change of stratum and at intervals not to exceed five (5) feet. At these points, advancement of the borehole shall be stopped and the casing advanced as required, but to a depth no greater than the maximum depth of jetting or chopping, and all material removed from inside the casing or borehole. The use of water for cleaning out the casing between samples will be required unless hollow stem auger methods are used, and only approved shielded chopping bits may be used for cleaning the casing or borehole preparatory to taking spoon samples. The majority of the samples shall be obtained by driving a 35 mm. (1-3/8 in.) I.D., 61 cm. (24 in.) long split-spoon sampler into the undisturbed material below the bottom of the casing or borehole.

Seclected samples shall be obtained by driving a 63.5 mm. (2-1/2 in.) I.D., 61 cm. (24 in. long), split-spoon sampler into the undisturbed material below the bottom of the casing or borehole. The split-spoon sampler shall be constructed in accordance with ASTM Designation D1586-67.

2.05.2 Recovery. If difficulty is experienced in recovering samples, the split-spoon samplers shall be equipped at the top with a reliabile check valve and at the bottom with a soil catcher. Flap valves will be allowed only with the approval of the Geotechnical Engineer and the Hydrogeologist.

2.05.3 Standard Penetration. To standardize determination of the relative resistance of the various strata, the 35 mm.

(1-3/8 in.) split-spoon sampler shall be driven by a 63.6 Kg. (140 pound) weight hammer having a 76 cm. (30 in.) drop. The number of blows for each 15 cm. (6 inches) of penetration shall be recorded for 45 cm. (18 inches) of penetration.

2.05.4 "Refusal". "Refusal" is defined as less than 2.5 cm. (1 in.) penetration of an open end "A" rod driven by at least 100 blows of a 136 Kg. (300 pound) weight hammer having a 45 cm. (18 in.) drop. All "refusals" will be confirmed by the Geotechnical Engineer before abandoning the boring, or it will constitute an inacceptable unit for pay purposes.

2.06 Rock Coring

At those boring locations designated on the contract plans as core borings, or at other locations to be determined by the Geotechnical Engineer and the Hydrogeologist, the Contractor shall take continuous rock core samples by means of a diamond drill to a depth directed by the Geotechnical Engineer or the Hydrogeologist. In general, however, rock coring will probably not be directed.

The term rock shall be applied to any material that cannot be penetrated by the chopping bit. Soft or decomposed rock shall be sampled with a driven sampler whenever possible. When drilling through rock or boulders, the chopping bit shall be used to break up all disintegrated rock and the casing shall be firmly seated on rock by driving and washing out before inserting the diamond bit. The diamond core bit shall be started in the hole and the rock shall be drilled until required depth is reached. When the core is broken off, it shall be withdrawn, labeled, and stored before the drilling is continued.

Drilling into rock shall be done with a core barrel and diamond bit which will produce a core 41.3 cm. (1-5/8 in.) in diameter. The drilling machine shall be of the rotary or hydraulically operated variety.

The Contractor shall exercise due care to obtain satisfactory cores with at least 85 percent recovery in bedrock and boulders. In cases where it is impossible to obtain the required percentage of recovery, the Contractor shall maintain a maximum percentage by regulating the speed and rate of feed of his drill, amount of drill water and remove the cores as frequently as directed. He will also make use of special equipment currently on the market. A Christensen Series 200, Hi-Cor core barrel or equivalent will be used for coring bedrock. The required core barrel will be 1.5 m. (5 ft.) in length. If it proves to be impossible to obtain the necessary recovery through no fault of the Contractor after he has used special care, methods, and equipment, the Geotechnical Engineer may relax the percentage requirements to fit the field conditions.

2.07 Stationary Piston Tube Sampling

Stationary piston tube samples shall be taken with a thin-wall tube sampler, containing a close fitting piston operated by a separate piston rod and a sampler head with appropriate spring rod check. The sampler shall be similar or equal to the Stationary Piston Tube Sampler, as manufactured by Acker Drilling Company, Inc., Scranton, Pennsylvania, Assembly No. 1510. The sampler tube shall be 76.2 mm. (3.0 in.) maximum O.D. with 16 gauge wall thickness and be 76.2 cm. (30 in.) long, shall be provided with a sharp cutting edge and positive inside clearance and shall be bright, clean, and free from rust. The end of the tube shall be drawn in so the I.D. of the cutting edge shall be 0.4 mm. (1/64 in.) less than the I.D. of the sampler tube.

Samples shall be taken in a "piston clamped flush position" to produce samples 61 cm. (24 in.) long and suitable for laboratory examination and tests in accordance with the best standards.

Preparatory to taking an undisturbed sample, the bottom of the borehole shall be cleaned thoroughly to the required sampling depth. This shall be done by washing to within 7 to 10 cm. (3 to 4 in.) of the desired depth with a shielded jet type clean out auger, similar or equal to Sprague & Henwood, Inc., Assembly No. A15239. The wash water shall be shut off and the clean out auger rotated down by hand the remaining few inches to the desired depth.

The sampler shall be jacked or forced into the ground without rotation in one continuous operation under steady pressure at a rate of from 15 cm. (0.5 ft.) to 30 cm. (1.0 ft.) per second. After the sampler has been forced into the soil at the required depth, a minimum waiting period of 10 minutes shall be required before sample withdrawal. The drill rods shall be rotated to shear of the end of the sample, and the sample then shall be withdrawn with extreme care to minimize sample disturbance.

The sampler tube with sample shall be detached from the head of the mechanism in a manner to cause as little disturbance as possible to the sample. A minimum of 30 cm. (12 in.) of recovery of undisturbed cohesive soils will be accepted for payment purposes. In the event that the recovery is less than 30 cm. (12 in.) the Contractor will be required to rewash the hole to 30 cm. (1.0 ft.) below the point of maximum penetration and repeat the same procedure and obtain a satisfactory sample.

All disturbed material shall be removed from the top of the tube and a one-inch wax seal shall be placed at the top and bottom of the remaining undisturbed material. Empty portions of the tube shall be filled with firmly pressed sawdust or sand and the tube ends shall be sealed with a metal or plastic cap, friction tape, or wax. Wax shall be of the micro-crystalline variety such as Socony Vacuum Product 2300 or equal. Parafin was will not be acceptable as a sealant. The samples will be received by the Geotechnical Engineer for transportation to the laboratory facilities.

2.08 Thin-Wall Tube Sampling

Thin-wall tube samples shall be taken with a thin-wall tube sampler 47.6 mm. (1-7/8 in.) minimum I.D. and 50.8 mm. (2 in.) maximum O.D. and which shall be bright, clean, and free from rust and shall be provided with a sharp cutting edge and a positive inside clearance. The end of the tube shall be drawn in, so that the I.D. of the cutting edge shall be 0.4 mm. (1/64 in.) less than the I.D. of the sampler tube. The tubes shall be of such length to recover a 61 cm. (24 in.) sample. The tube shall be forced into the soil without rotation a distance of 61 cm. (24 in.) in one continuous operation at the rate of from 15 to 30 cm. (1/2 to one foot) per second by jacking or pressing.

In the event stiff or hard cohesive soils are encountered, the Contractor will be required to drive the sample tube into the soil and record the blows for each 15 cm. (6 in.) of penetration. Samples shall be sealed in the same manner as is provided herein for stationary piston samples.

2.09 Field Vane Shear Testing

The in-place shear strengths of cohesive waste materials shall be measured by means of field vane shear tests. The two required vanes shall be of the 4-bladed type. One vane shall be approximately 76 mm. (3 in.) in diameter and approximately 15 cm. (6 in.) in length and the other shall be approximately 51 mm. (2 in.) in diameter and approximately 10 cm. (4 in.) in length, as manufactured by Sprague & Henwood, or an approved equal.

A minimum of three vanes of each type will be required on site at all times in the event that a vane becomes damaged or destroyed.

A ball bearing casing guide shall be attached to the drill rods 60 cm. (2 ft.) above the vane and additional ball bearing casing guides shall be provided for each 6 mm. (20 ft.) of drill rods required thereafter. All drill rods shall be made up tightly. The vane shall be pushed or driven into the soil below the bottom of the hole in a manner that will prevent rotation during insertion. The bottom of the vane shall be inserted 46 cm. (18 in.) into the undisturbed soil at the bottom of the hole.

After insertion, the drill rods shall be clamped securely to a thrust type ball bearing reacting against the casing, this bearing should support the entire weight of the vane and rods during the test. The rotation of the vane shall be accomplished by means of a mechanical drive mechanism which shall produce a uniform rate of rotation of about one degree every 10 seconds

(6 degrees per minute). Accurately calibrated torque mechanisms or proving rings with maximum readings of 7.6 Kgm (50 ft/lbs) shall be provided to measure the applied torque. Acceptable equipment is the Acker Precision Drive, or equal. One man shall rotate the vane while another observes the torque gauge. Special attention shall be given to determine the maximum torque registered.

The remolded shear strength shall be determined in the same manner after rotating the drill rods about 12 revolutions. During the tests, readings of time, applied torque and angular rotation should be recorded at 15-sec. intervals until the maximum torque is achieved.

2.10 Groundwater Observation Wells

The Contractor shall install groundwater observation wells in completed boreholes at the approximate locations shown on the contract plans in the manner described herein. The depth to the bottom of the well installation will vary below existing ground surface. The exact depth will be determined by the Hydrogeologist during the exploration program. The observation wells shall consist of a minimum inside diameter of 51 mm. (2.0 in.) I.D., Schedule 80, PVC pipe (to be supplied by the Contractor). Slotted PVC wellpoint sections shall be available in 1.5 and 3.0 m. (5 and 10 ft.) lengths with the slot pattern consisting of 3 rows of slots along the length of the pipe, each row spaced evenly around the pipe circumference 120 degrees apart, 0.5 mm. (0.020 in.) wide, and spaced 6.3 mm. (0.25 in.) on center. Pre-slotted "hydrophylic" P.V.C. pipe which most closely approaches the above recommended slot pattern may also be utilized for the observation well installations. No metallic fittings or parts will be acceptable for the installation. The Contractor shall make up all observation wells and shall install the completed assembly in the borehole made for this purpose. Standard Ottawa sand, 20-30 ASTM Designation C190 shall be poured down and around the selected point to approximately 1.5 m. (5.0 ft.) above the point.

A clean, coarse to fine sand shall be placed in increments and the casing shall be "bumped back" in increments until the hole is completely backfilled with sand to tbe required depth. Selected seals may be required to isolate the wellpoint in certain stratum. This will be accomplished by slowly dropping bentonite "Pi pellets", until a seal approximately 60 cm. (2 ft.) in thickness has been constructed at the desired elevation.

Observation wells will not be placed in roadways or other paved areas. Observation wells will be completed with a 90 cm. (3 ft.) minimum height of stand pipe rising above surrounding ground. This pipe will be a suitable length of 63.5 mm. (2-1/2 in.) minimum diameter pipe, with vented locking cap and shall be cement grouted at ground surface to protect the installation (See Figure B for details of the protective casing and locking cap). The stand pipe will be painted a suitably bright color to minimize damage from impact by moving equipment.

BRUNING 44-141 35356

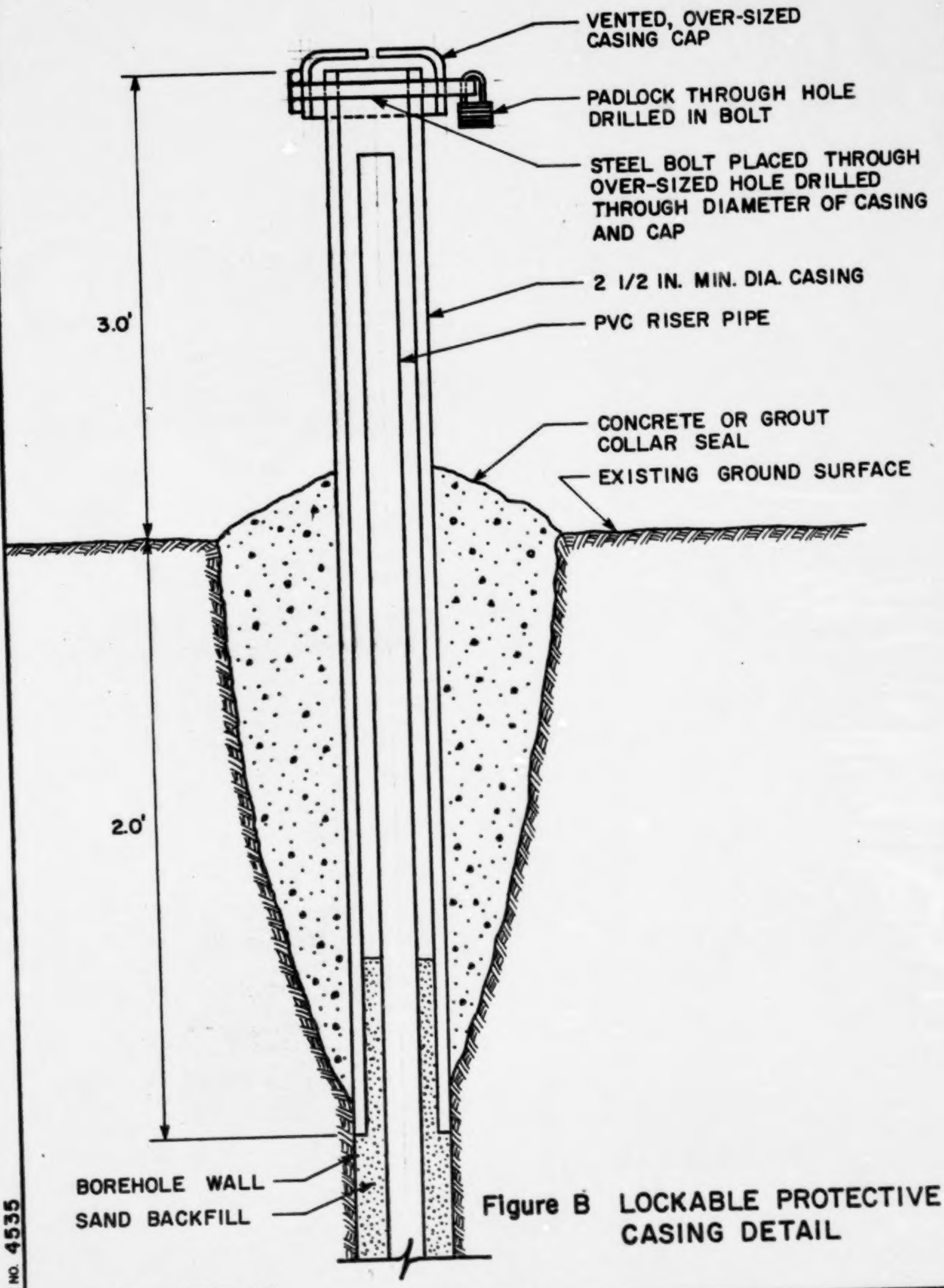

VENTED, OVER-SIZED CASING CAP
PADLOCK THROUGH HOLE DRILLED IN BOLT
STEEL BOLT PLACED THROUGH OVER-SIZED HOLE DRILLED THROUGH DIAMETER OF CASING AND CAP
2 1/2 IN. MIN. DIA. CASING
PVC RISER PIPE
3.0'
CONCRETE OR GROUT COLLAR SEAL
EXISTING GROUND SURFACE
2.0'
BOREHOLE WALL
SAND BACKFILL

Figure B LOCKABLE PROTECTIVE CASING DETAIL

FILE NO. 4535

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

All observation well miscellaneous materials, including protective devices, will be supplied by the Contractor.

Upon completion, the Contractor shall flush the observation well to demonstrate proper operation. The well flushing shall be done under the supervision of tbe Hydrogeologist. Typical observation well installations are shown in Figures C and D.

2.11 Piezometers

The Contractor shall provide and install piezometers in the completed boreholes at the approximate locations shown on the Contract plans and in the manner described herein. The depths to the bottom of the piezometers will vary below existing ground surface. The exact depth will be determined by the Hydrogeologist during the exploration program. It is anticipated that a maximum of two piezometers and one shallow observation well may be installed in each 102 mm. (4 in.) I.D. PVC pipe-cased boring. All boreholes shall be flushed with clean, fresh water until, in the opinion of the Hydrogeologst, the borehole is acceptable for installation of the piezometer.

The piezometer will consist of a porous screen-point tip, manufactured from a permeable filter material with a 50 micron mesh, which is referred to as Vyon. The PVC point assembly, shall have no metallic fittings and shall be attached to PVC riser pipe and installed in the completed borehole by the Contractor. The Contractor will supply all piezometers, riser pipe, and necessary materials to complete the installation.

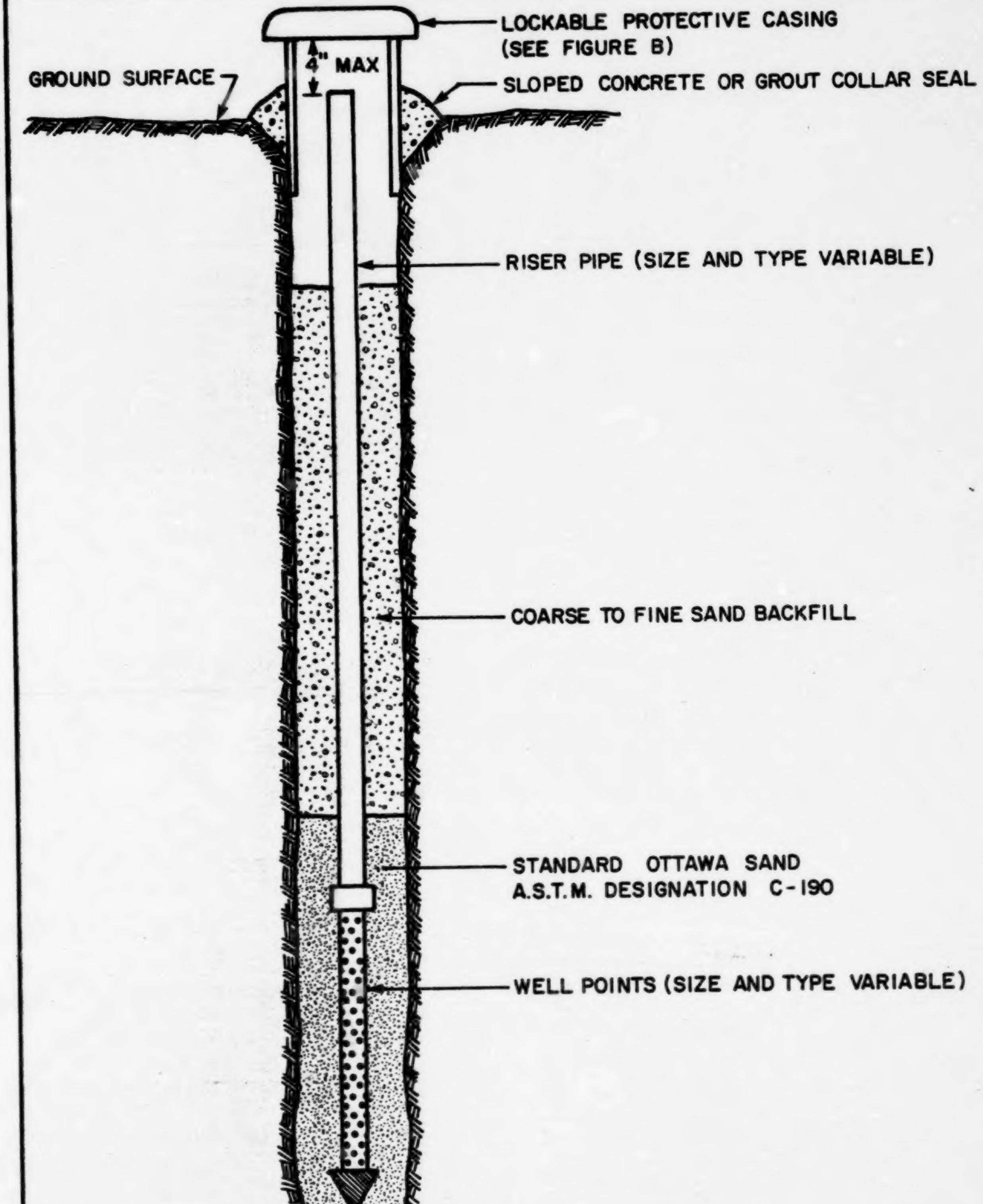

LOCKABLE PROTECTIVE CASING
(SEE FIGURE B)
4" MAX
GROUND SURFACE
SLOPED CONCRETE OR GROUT COLLAR SEAL
RISER PIPE (SIZE AND TYPE VARIABLE)
COARSE TO FINE SAND BACKFILL
STANDARD OTTAWA SAND
A.S.T.M. DESIGNATION C-190
WELL POINTS (SIZE AND TYPE VARIABLE)

Figure C OBSERVATION WELL (AVERAGING TYPE)

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

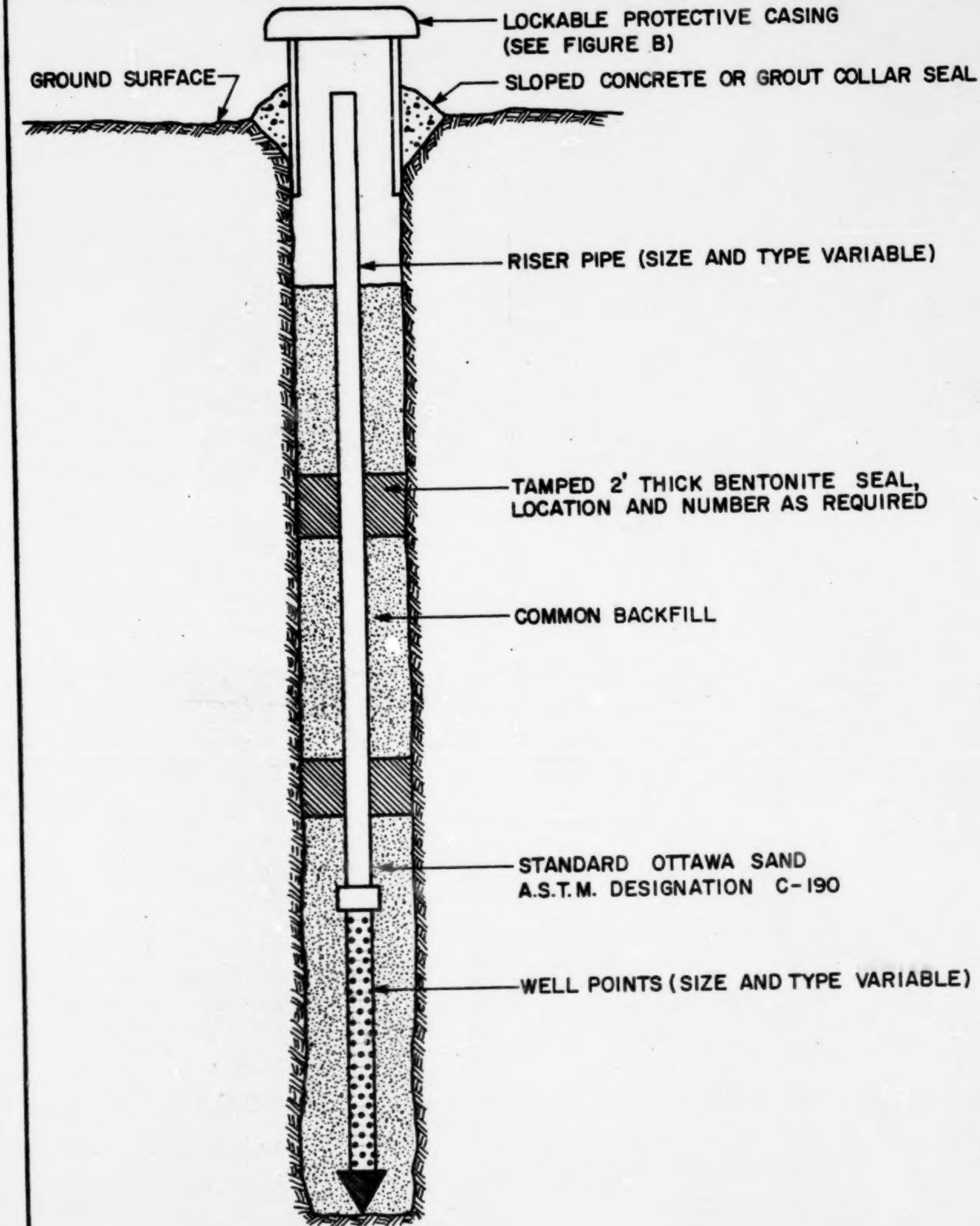

LOCKABLE PROTECTIVE CASING
(SEE FIGURE B)
GROUND SURFACE
SLOPED CONCRETE OR GROUT COLLAR SEAL
RISER PIPE (SIZE AND TYPE VARIABLE)
TAMPED 2' THICK BENTONITE SEAL,
LOCATION AND NUMBER AS REQUIRED
COMMON BACKFILL
STANDARD OTTAWA SAND
A.S.T.M. DESIGNATION C-190
WELL POINTS (SIZE AND TYPE VARIABLE)

Figure D OBSERVATION WELL (ISOLATED TYPE)

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

A variety of piezometer points will be supplied by the Contractor and readily available during the conduct of the exploration program for each site. Two (2) piezometer point diameters [25 mm. (1.0 in.) and 50 mm. (2.0 in.) inside diameter] and two (2) piezometer point lengths [0.6 meters (2.0 ft.) and 1.2 meters (4.0 ft.)] for a total of four (4) different piezometer points will be required with a minimum of ten (10) points of each type immediately available at the site during the exploration program. Two (2) diameters of P.V.C. piezometer riser pipe will also be required [20 mm. (3/4 in.) and 50 mm. (2.0 in.) inside diameter]. These riser pipes must have the capacity of being securely attached to the piezometer points discussed above.

The varying hydrogeological conditions within each specific site area will dictate the type, size and depth of the piezometer to be installed for groundwater monitoring and sample collection purposes.

Generally, the piezometers will be installed in separate boreholes, however, it may be advantageous in specific situations to install at least two piezometers in each borehole, in addition to a near surface observation well (see Figure E). Each piezometer shall be isolated and sealed above the piezometer tip by placing an impermeable seal consisting of tamped alternating layers of bentonite pellets and sand. The borehole shall then be backfilled with sand to the elevation of the lower seal for the observa-

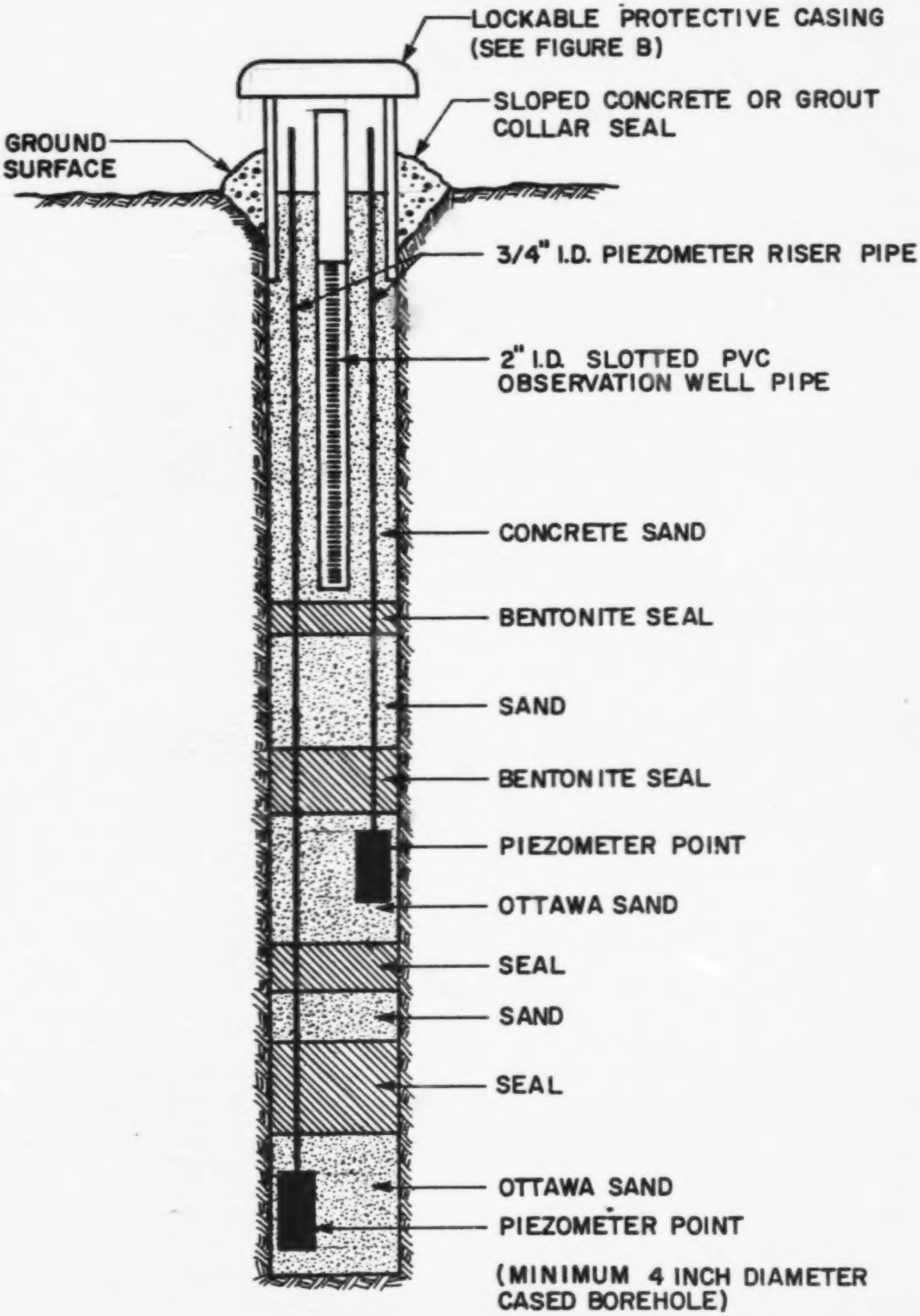

LOCKABLE PROTECTIVE CASING
(SEE FIGURE B)
SLOPED CONCRETE OR GROUT
COLLAR SEAL
GROUND
SURFACE
3/4" I.D. PIEZOMETER RISER PIPE
2" I.D. SLOTTED PVC
OBSERVATION WELL PIPE
CONCRETE SAND
BENTONITE SEAL
SAND
BENTONITE SEAL
PIEZOMETER POINT
OTTAWA SAND
SEAL
SAND
SEAL
OTTAWA SAND
PIEZOMETER POINT
(MINIMUM 4 INCH DIAMETER
CASED BOREHOLE)

Figure E MULTIPLE PIEZOMETER/OBSERVATION WELL INSTALLATION

tion well. The specified piezometers will be capable of withdrawal of water samples through approved sample recovery devices.

To facilitate the water sampling of various levels within the same aquifer, multiple piezometers may be installed in the completed borehole without the intervening, impermeable seals.

Piezometer installations will follow the general guidelines outlined below:

a. Backfill the borehole with a mixture of bentonite and sand, tamped in layers to the required installation depth.

b. Assemble the piezometer tip and PVC riser pipe providing about 1.5 meters (5.0 ft.) of excess pipe; measure the length of pipe to the bottom of piezometer unit.

c. Connect the open end of the PVC pipe to a flushing tank and flush the pipe and piezometer tip.

d. Maintain flushing as each section of pipe is added. Lower the piezometer tip until it rests on top of the sand at the desired elevation.

e. Hold the PVC riser pipe to prevent twisting or kinking during remaining operations.

f. Pour sufficient Ottawa sand around the tip until the sand is about 15 cm. (6 in.) above the top of the piezometer. Permanently disconnect the flushing tank and check the height of the sand using a tamping hammer and the reference mark on the cable. Bump the casing back if used, to within 8 to 15 cm. (3 to 6 in.) of the top of sand backfill, taking care not to move the piezometer vertically.

g. Backfill the hole with concrete sand to a depth of 60 cm. (2 ft.) above the piezometer and place a 60 cm. (24 in.) minimum thick seal, if required according to the following procedures:

    1. Place a 15 cm. (6 in.) layer of dry bentonite pellets; predetermine the required volume.
    2. Place an 8 cm. (3 in.) layer of concrete sand over the bentonite.
    3. Tamp the sand with a minimum of 20 blows of the tamping hammer, each blow having a height of fall of at least 15 cm. (6 in.).
    4. Repeat the procedure to construct a minimum seal thickness of 60 cm. (24 in.). Record the depth to the top of seal.

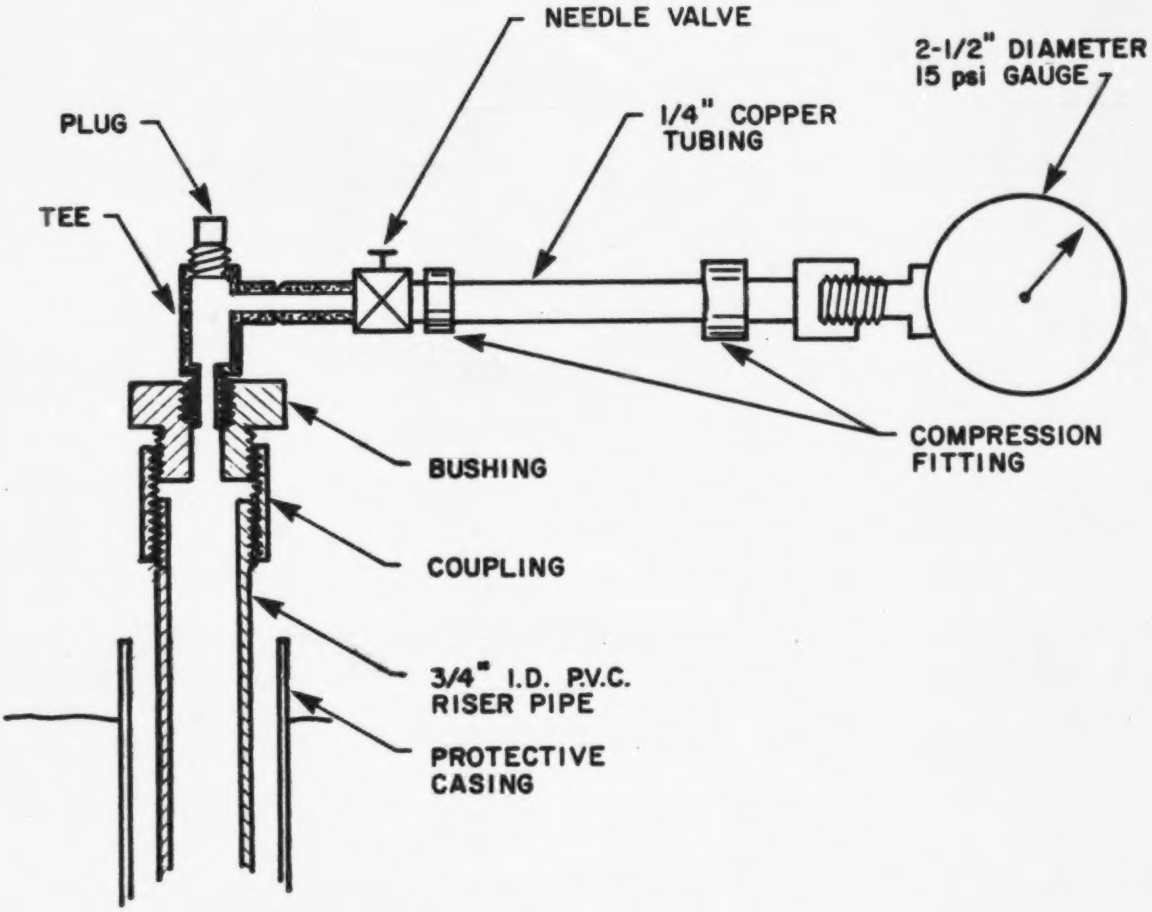
h. Backfill the hole with concrete sand for an additional three feet. Place another 60 cm. (2 ft.) thick seal, as indicated in Step f.

i. Clearly mark the PVC riser pipe as to which piezometer it is attached to, and cut the pipe off flush with the top of the protective surface casing similar to that described under Section 2.10, Observation Wells.

Although piezometer pressure measurement readings are generally not anticipated, the Contractor is required to have a minimum of two (2) removable piezometer pressure gauge attachments with the correct riser pipe adapter couplings, bushings and threading tools immediately available on site during the conduct of the field exploration program. Figure F, Piezometer Pressure Measurement Gauge, shows a simple schematic diagram of a suitable pressure gauge attachment. The pressure gauge attachment would be installed either permanently or temporarily, if major artesian water conditions were encountered in the borehole.

2.12 Water Quality Sampling

The groundwater observation wells and piezometers are to be installed throughout the specific site areas for the purpose of monitoring groundwater level and fluctuations and artesian or perched water conditions. In addition, the observation wells and piezometers will be utilized for groundwater sampling of selective horizons.


NEEDLE VALVE
2-1/2" DIAMETER 15 psi GAUGE
1/4" COPPER TUBING
PLUG
TEE
COMPRESSION FITTING
BUSHING
COUPLING
3/4" I.D. P.V.C. RISER PIPE
PROTECTIVE CASING

(NOT TO SCALE)

Figure F PIEZOMETER PRESSURE MEASUREMENT GAUGE

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

Portable nitrogen or other low-activity gas will be used to pressure-displace samples (depths more than 10 m.) or peristaltic vacuum pumps (depth less than 10 m.) will be used to retrieve representative water samples.

ADL/TRW S&A field teams will monitor water levels in individual borings before sampling.

2.13 Grouting

All test borings which are not utilized for the installation of observation wells and piezometers will be cement grouted from the bottom of the borehole, upward to the collar, in order to construct a totally impermeable barrier to fluid transport. All grout mixes and procedures must be approved by the Geotechnical Engineer or the Hydrogeologist before commencing the work.

2.14 Field Permeability Tests

2.14.1 General. At locations and depths designated by the Hydrogeologist, the Contractor shall perform field permeability tests within a borehole. The permeability tests will be performed in the following manner: At selected locations, the boring will be extended below the bottom of the casing by driving a 76.2 mm. (3 in.) O.D. split-spoon sampler or by drilling to a depth specified by the Hydrogeologist. The hole shall be thoroughly cleaned of all material. The Hydrogeologist shall designate the testing procedure to be performed by one (1) or more of the three (3) methods described hereinafter. Accurate measurements of the depths of casing and boring are critical. Upon completion of the test, the boring shall be sounded to determine if the test hole has maintained its dimensions during testing. The rising water level method will be the preferred technique.

The computational basis for permeability calculations will be as specified by the hydrogeologist on review of initial site hydrogeological findings.

The Contractor will carry several Johnson-type, screw-connected well screens for temporary installation in single-position borings, as directed by the hydrogeologist.

2.14.2 Rising Water Level Method. This method requires that the water inside the casing be bailed to its lowest practical depth, and this depth recorded. The subsequent rate of rise of the water level in the casing is then determined at one (1), two (2), and five (5) minutes after the start of the test and at five (5) minute intervals therafter. The test shall continue until the rate of rise of the water level is less than 30 cm. (1 ft.) per five (5) minute interval, or until thirty (30) minutes has elapsed since the start of the test. The depth to the water level shall be measured in meters and centimeters. If the soil runs into the casing when performing this type of test (determined by sounding with drill rods after the test has been performed), the test shall not be considered as being valid and either the Falling Water Level Method or Constant Water Level Method, as directed by the Hydrogeologist, may be required to be performed. Prior to performing a different type of test, the casing shall again be cleaned and flushed with clean water.

2.14.3 Falling Water Level Method

The casing shall be filled with water and the rate of drop in the water level in the casing determined by observing the depth of the water surface below the top of the casing at one (1), two (2), and five (5) minute intervals thereafter. The record of measurements shall include the depth of the water surface below the top of the casing before and after filling of the casing, the time and the amount of the drop measured from the start of testing for each observation. The depth to the water level shall be measured in meters and centimeters.

Observations shall be continued until the rate of drop in the water level is less than 30 cm. (1 ft.) per five (5) minute interval or until thirty (30) minutes have elapsed since the start of the test. If the drop in the water level, as described above, is too rapid to permit accurate observations to be made, the Hydrogeologist may instruct the Contractor to perform a permeability test using the Constant Water Level Method.

2.14.4 Constant Water Level Method

This method requires that water be added into the casing until the casing is full. After this, water shall be added in accurately measured quantities by pouring from calibrated containers, or by pumping through a water meter at a rate of flow sufficient to maintain a constant water level at or very near the top of the casing for a period of not less than ten (10) minutes nor more than thirty (30) minutes. The record of measurements shall include the depth of the water surface below the top of the casing before filling, the length of time during which the water in the casing was maintained at a constant level, and the amount of water added to maintain the constant water level in the casing at one (1), two (2), and five (5) minutes, and at five (5) minute intervals thereafter.

2.15 Test For Running Sand

Any time that sand, coarse or fine, is encountered, the Hydrogeologist may require that the following test be made to determine if the water content and the pressure upon the material is sufficient to cause it to "run" when unconfined.

Upon striking sand, a sample of the material shall be obtained by the penetration method. The casing shall then be advanced into the sand 60 cm. (2 ft.) below the elevation at which the sand was encountered, and carefully washed out to the bottom. The hole shall be allowed to stand ten (10) minutes, and the elevation at which the sand then stands in the casing shall be measured. The water in tbe casing shall be removed to a point 1.5 m. (5 ft.) above the bottom of the casing to produce an unbalanced hydrostatic condition, and the elevation of the top of the sand shall then be measured.

2.16 Machine-Excavated Test Pits

Test pits shall be excavated within selected project site limits at locations directed by the Geotechnical Engineer or the Hydrogeologist to better define the soil conditions and obtain bag samples of granular soils. A rubber-tired, tractor-mounted backhoe capable of excavating to a maximum depth of 3.6 m. (12 ft.) with a bucket capacity of at least 0.3 cu. m. (3/8 cu. yd.) is required. It shall be equipped with a front end loader attachment to facilitate backfilling the test pits when completed. Sides of test pits greater than 1.5 m. (5 ft.) deep shall be properly sloped to prevent cave in, to allow the site Engineer or Hydrogeologist to examine the soil from ground surface and to obtain samples from the backhoe bucket.

When a test pit has been completed and examined by the site Engineer of Hydrogeologist, and the necessary samples taken, it shall be immediately backfilled. No sheeting, shoring, pumping, or pavement restoration will be required as part of the test pitting.

An acceptable day of test pit work shall consist of a suitable backhoe, supplied by the Contractor, and a competent operator working or being ready to work at the site, for a period of eight (8) hours during a day on which test pit work has been requested by the site Engineer or Hydrogeologist. The test pits will be excavated during the boring program.

The Contractor will not be required to perform layout or submit records for the test pits. The Project Geotechnical Engineer or Hydrogeologist will furnish field personnel to log and sample the test pits.

2.17 Preserving Samples

2.17.1 Split-Spoon Samples. Representative specimens of each sample shall be preserved. Upon describing the samples, they shall be divided equally in half and placed into two jars. The containers for preserving driven samples shall be large mouth, round, screwed top, air tight, clear glass jars. Size of jars shall be 0.25 liter (8 oz.) for 35 mm. (1-3/8 in.) samples and 0.38 liter (12 oz.) for 63 mm. (2-1/2 in.) samples. The specimens shall be placed in the jars as soon as taken in order that the original moisture in the material may be preserved. The jars shall be tightly capped and shall be suitably boxed, marked, and identified with legible labels, as directed by the Geotechnical Engineer. These labels shall show the date, boring number, sample number, and depth at which the sample was taken and the blow count for each 15 cm. (6 in.) of penetration.

In no case shall the samples be allowed to freeze.

2.17.2 Rock Cores Rock core is not planned for this project. However, if directed, the core shall be carefully placed in suitable wooden boxes so partitioned that the rock from each core run will be kept separated by wood blocks at either end. Rock cores shall be suitably labeled and arranged neatly in the boxes in the sequence in which the material was removed from the hole with the depths of the top and bottom of the run and the amount of recovery clearly marked.

Core boxes shall be constructed of dressed lumber, about 1.5 m. (5 ft.) in length, and with a capacity for about 6 m. (20 ft.) of core in each box. Core boxes shall be equipped with all necessary partitions, covers, hinges, screws for holding down the cover, and suitable identification plates and tags. All precautions will be taken to minimize disturbance of the rock core samples during transport.

Selected specimen(s) of rock core may be designated by the Geotechnical Engineer for special packing and preservation. The selected specimen(s) shall be wrapped with aluminum foil, then placed inside a heavy duty cardboard cylinder and sealed at both ends with a flexible micro-crystalline wax.

2.17.3 Thin-Wall and Stationary Piston Tube Samples

All samples shall be preserved, the ends of the tube shall be filled with wax, placed in increments to prevent voids, and finally sealed with a metal cap, friction tape and wax. The wax used for the preservation of samples shall be flexible micro-crystalline wax such as Socony

Vacuum Product 2300, or equivalent. The tube samples shall not be allowed to freeze or be stored in the direct sun for long periods of time. The tube samples should be stored and transported in the vertical-up position and protected by resilient packing material for transportation.

2.18 Submission of Samples

All samples obtained during the contract shall be delivered by the Contractor to the office of the Geotechnical Engineer at the completion of the field exploration program.

2.19 Records

The Contractor shall keep complete field records of each boring, and these records shall show his interpretation of the results of the borings as to the nature of the subsurface conditions. Such records shall be furnished to the Hydrogeologist or Geotechnical Engineer at the site, upon completion of each boring. The field records shall contain, but not be limited to, the following information:

2.19.1 General Information.

a) Date and time and project number.

b) Geotechnical Engineer, Hydrogeologist and Contractor, and assigned lead personnel as part of the form heading.

c) Location and identifying number of test boring and reference to survey data.

d) Ground elevation at hole.

e) The Engineer will be responsible for recording any detailed information associated with special testing, such as field vane shear and permeability tests.

f) Size, length, and elevation of bottom of casing used in each borehole.

g) Elevation of groundwater table at each hole and time of observation.

h) Description of samples.

i) Force required to press tubes and recovery (to be recorded by driller in PSI off the pressure gauge).

j) Depth of special tests.

2.19.2 Rock Cores

a) Type and size of core barrel used.

b) Length of core recovered for each length drilled. Depth range of runs.

c) Elevation at which rock was encountered.

d) Elevation of bottom of hole.

e) Description of rock.

f) Time required to drill each foot.

g) Depth of loss of water (partial or total loss).

2.19.3 Miscellaneous Data

a) Type, size, and depth of observation wells and piezometers.

b) Depth of water at completion of boring and 24 hours after completion.

c) Depth and type of unusual conditions.

d) Depth of field vane shear tests and permeability tests.

2.20 Drilling Procedure for Measuring Density of Waste Stockpiles Using Nuclear Depth Density Equipment

2.20.1 Equipment The Geotechnical Engineer will supply the special equipment and expertise to conduct the Nuclear Depth Density tests. Conventional drilling and sampling equipment will be supplied by the Contractor and includes:

a) Drilling rig with 63.6 Kg. (140 lbs.) drop hammer and associated drilling equipment.

b) 69.8 mm. (2-3/4 in.) I.D. hollow stem augers in sufficient quantity to extend 6 m. (20 ft.) below the bottom of the waste stockpile.

c) Two (2) split spoons, 51 mm. (2 in.) O.D. One split spoon, 1.2 m. (4 ft.) long, one split spoon 45 cm. (1.5 ft.) long, (Standard).

d) Aluminum (extruded) or steel taping of varying lengths. Basically cut in lengths of 1.8, 3.6, 6.3, 9.3, 12.3 m. (6, 12, 21, 31, 41 ft., respectively).

e) Rubber plugs for bottom of tubes.

f) Dummy steel probe and rope.

g) Hacksaw, marking pencils, fine rattail file.

h) Measuring tape on marking stick.

i) Air tight sample jar.

j) Nuclear depth gauges and surface gauge (Geotechnical Engineer).

2.20.2 Procedure

a) Position rig over test location and determine the surface elevation. Record elevation on work sheet.

b) Start the hole using the 1.2 m. (4 ft.) long split-spoon. Use standard penetration methods to advance hole 1.2 m. (4 ft.).

c) Carefully extract split-spoon and place entire recovered material in sample jars. Label jars with the depth and location number.

d) Repeat steps b and c to advance hole from 1.2 to 2.4 m. (4 to 8 ft.).

e) Repeat steps b and c to advance hole from 2.4 to 3.6 m. (8 to 12 ft.).

f) Place aluminum (or steel) tube in hole after rubber plug has been placed in bottom of the tube. Push tube to 11 feet. DO NOT PUSH TUBING BEYOND PENETRATION HOLE.

g) Remove any burrs at top of tubing, or cut off any flared portions, or tubing which has been bent.

h) Place depth probe on tube.

i) See "Field Procedure for Operating Depth Density Gauges, Model 1251 and 1351", and make field counts on 1-ft. increments in the tube.

j) Extract aluminum (or steel) increments in the tube and lay aside for reuse.

k) Place 3 m. (10 ft.) of hollow stem auger in hole.

l) Advancing the hole from 3.6 to 7.2 m. (12 to 24 ft.) and repeat steps b to j.

m) Place a second 3.0 m. (10 ft.) of hollow stem auger.

n) Advance hole to required depth into the material by repeating steps b to m.

o) When the hole has been advanced to within 1.5 to 2.1 m. (5 to 7 ft.) of the estimated original soil elevation, constant sampling methods should be used, with 45 cm. (18 in.) split spoon.

p) Collect approximately 45 to 75 Kg (100 to 150 lbs.) of waste material from augering operations. This will be used as part of a composite 700 to 800 samples from all auger holes, which will be used to calibrate the nuclear gauge to the waste.

2.21 Test Pit Procedure for Measuring Density of Waste Stockpiles Using Nuclear Density Equipment

2.21.1 Equipment. The Geotechnical Engineer will supply the special equipment and expertise to conduct the Nuclear Depth Density tests.

a) Nuclear surface gauge with 30 cm. (12 in.) probe.

b) Three (3) meter (10 ft.) of 2x4 lumber.

c) 3 m. (10 ft.) x 3 m. (10 ft.) piece of 4 or 6 mil visquene.

d) Shovel or spade.

e) Balance with a 45 Kg. (100 lbs.) capacity.

f) 400 liters (100 gallons) of water.

g) 20 liters (5 gallons) bucket.

2.21.2 Procedure

a) Locate the test pit within 3.0 m. (10 ft.) of the depth of test holes.

b) Form a box with the 2x4 lumber, which has a length of 60 cm. (2 ft.). Square and level the forms over the test location.

c) Make a field density test on the surface of the coal. Refer to "Operating Procedures for 3400 Series Nuclear Gauges".

d) Remove gauge and excavate a hole to a depth of 60 cm. (2.0 ft.) below the bottom of the wood forms. Carefully level the bottom, making sure the sides of the hole are nearly vertical. RETAIN ALL WASTE FROM EXCAVATION.

e) Weigh the waste from the excavation to the nearest 0.045 Kg. (0.1 lb.) and record the weight.

f) Repeat step c on the bottom of the excavation.

g) Place the visquene as a liner in the test pit up to the top of the wood forms.

h) Fill a 20 liter (5 gallons) bucket with water and weigh to the nearest 0.045 Kg. (0.1 lb.) and pour in lined test pit.

i) Repeat step h until water is up to the bottom of the wood frame, forming the surface of the waste material.

j) Total the weight of the water placed in the test pit and record.

k) Return data to Project Engineer for evaluation.

2.21.3 Depth Density Gauges Model 1251 and 1351 Connections

a) With the scaler in the OFF position, connect either the moisture gauge or density gauge to the scaler. Be sure the adapters are free of dust and are well seated.

b) The scaler must be placed at a 45 degree angle from the horizontal and the function knobs should be in the following positions:

- Time Selector Knob = 1 minute
- Gain knob = 3 minutes
- When the moisture gauge is connected, the HV (High Voltage) knob is at 1500v.
- When the density gauge is connected, the HV knob is at 1000V.

c) Turn on the scaler. Move the function selector knob to the "BATT" position and check the battery charge. The needle on the Volt-Rate meter should be between the heavy line on the lower scale of the meter. If the needle is below the line, the scaler requires a charge before use.

d) Turn the function selector switch to the TEST position and push the "reset" and "start" buttons. Allow the scaler to count (dials lighted) for one minute. At the end of one minute, read the number of the indicators. This number must be 30720 (±16). If this number is not indicated, the scaler has malfunctioned and requires repair.

e) Using the voltage adjust knob, dial to the operating voltage printed on the gauge data plate for the gauge in use. The voltage is read on the lower scale of the Volt-Rate meter on the scaler.

f) Allow the gauge to warm up a minimum of 20 minutes, 30 minutes if below freezing temperature.

2.21.4 Field Calibration for Standard Counts Each gauge must be calibrated separately at least once each day; more if gauge is turned off for more than 45 minutes.

a) Move the gauge at least 9.0 m. (30 ft.) from any other gauges.

b) Allow the source which is stored inside the shielding container, to rest on the detent pins inside the container. Do not pull the source up against the top of the container.

c) Push the "reset" and "start" buttons, and make five (5) 1 minute counts, and average the counts. This is the standard count. Record this value on your work sheet on the inside of the Red Chart Book. If the average standard count is more than or less than 2.0 percent of the standard chart value, immediately notify the Project Engineer. Do not proceed until this problem has been evaluated.

2.21.5 Direct Moisture or Density Readings

a) Place the moisture or density gauge on the preplaced aluminum (or steel) tube. CAUTION: If the aluminum tube has predrilled holes for adapting to a drilling rig, do not allow the detent pins to open in these holes. Simply realign the probe by rotating in the direction required.

b) Squeeze the locking trigger on the cord and carefully lower the probe to the bottom of the tube.

c) Raise the probe 51 mm. (2 in.) from the bottom.

NOTE: The gauge connecting cord is marked in 51 mm. (2 in.) increments.

d) Make three (3) one (1) minute counts and record these values. Raise the probe 30 cm. (12 in.) and repeat the three (3) one (1) minute counts. Continue this process until the entire depth is tested.

e) Alternate method of making the three (3) field test counts. After raising the gauge two (2) inches from the bottom, make one (1) test count, and record the number. Raise the probe 10 cm. (4 in.) and make a second field count and record. Raise the probe 10 cm. (4 in.) and make a one (1) minute count. These three (3) readings are then averaged for the 30 cm. (1 ft.) depth measured.

f) Again do not have the gauges closer than 9.0 m. (30 ft.) to other gauges.

g) Divide the depth density measurement count by the density standard count and the depth moisture measurement count by the moisture standard count to obtain the count ratios. Turn to the proper tables and record the count ratios as wet density and moisture. Subtract the moisture from the wet density to obtain dry density. Divide the moisture by the dry density to obtain percent moisture. Divide the dry density by the maximum density to obtain percent compaction.

2.21.6 General Requirements:

a) Always wear your film badge when using the gauges.

b) When transporting the gauges, they must be locked in their respective shipping boxes.

c) Immediately report any damage or theft of the equipment to your supervisor.

2.22 Environmental Precautions

2.22.1 Legal Requirements All exploration activity must be conducted in accordance with applicable federal, state, and local laws, where required by law, permits and/or approvals must be obtained before commencing on exploration program or regulations pertaining to each project area. If unfamiliar with the legal requirements of the locality, contact the State Department of Natural Resources (or its equivalent agency) and the County and State Health Departments, or other appropriate authorities.

2.22.2 Access Roads Unless otherwise specified by applicable laws or regulations, access roads should be constructed according to the following guidelines.

a) Insofar as possible, access roads should be located on benches, ridges, and flatter slopes to minimize disturbance and enhance stability.

b) Access roads should not be constructed up a stream channel or so close that disturbed earth material may spill into the channel.

c) Road gradients should be kept low.

d) Streams should be crossed at or near right angles unless contouring down to the stream bed will result in less potential stream bank erosion. Stream crossings should be constructed to prevent water from flowing down the roadway.

e) Trees and vegetation should be cleared for only the essential width necessary to maintain slope stability and to serve traffic needs.

f) Drainage facilities should be constructed, as appropriate, as road construction progresses.

g) Materials which slough or slump onto the access road should be disposed of in the roadbed or in a designated fill area.

2.22.3 Drilling Unless otherwise specified by applicable laws or regulations, drilling activity should be conducted according to the following guidelines:

a) When water is to be used for drilling, the source of obtaining the water should be chosen carefully with regard to quality. The hauling or pumping of water shall be accomplished in clean, non-rust-scaled pipes or tanks. Permission shall be obtained when the water source is on private land or will interfere with public or private uses. Oil and fuel spills from the pump will be prevented.

b) Drill sites will not be located in stream beds (dry or flowing) as unnecessary erosion, sedimentation, and diversion of water into the ground may result. Drill sites will also be located at such distances from water wells or springs which will avoid damage to facilities or water quality.

c) Excavations and dozer work should be kept to a minimum. Reasonable efforts should be made to locate drill sites in areas where no dozer work is necessary. Site locations which require dozer work should be flagged ahead of time in a manner which does the least amount of damage to the property. A field representative for the subcontractor or the Geotechnical Engineer will work closely with the dozer operator in order to avoid over-grading which may result in excessive erosion and reclamation work.

d) Equipment should be periodically checked for oil and fuel leaks.

e) Regrading and restoring the site area to as close to its original condition, prior to drilling, will be required.

DAILY REPORT - TEST BORINGS

FILE NO. ______ DATE ______ REPORT NO. ______

PROJECT & LOCATION ______

CLIENT ______ INSPECTOR(S) ______ INSPECTION TIME ______

CONTRACTOR ______ DRILLER(S) ______

TYPE OF RIG(S) ______ NO. RIGS WORKING ______ WORKING TIME ______

NON-PRODUCTIVE TIME

WEATHER ______ EQUIPMENT BREAKDOWN ______ LATE ______ OTHER ______

WORK PRODUCTION TODAY

NO.	TYPE	OVER BURDEN (LIN. FT.)	ROCK CORE (LIN. FT.)	SHELBY TUBES TYPE & NO.	MISC. (WELLS ETC.)	MATERIALS ENCOUNTERED (TYPE & DEPTH RANGE)

STATUS OF TOTAL PRODUCTION

ITEM	BORING FOOTAGE & SAMPLES				NO. BORINGS		RIG-DAYS	
	TODAY	TOTAL TO DATE	ENG. EST.	% COMPLETE	TO DATE	REMAIN	TO DATE	REMAIN
STANDARD								
STANDARD								
CORE PREP								
CORE PREP								
ROCK CORE								
ROCK CORE								
SHELBY TUBES								
SHELBY TUBES								

SEE OTHER SIDE FOR SYMBOLS & REMARKS

HBA FORM 26 DEC. 69

HALEY & ALDRICH, INC. CAMBRIDGE, MASSACHUSETTS	**TEST BORING REPORT**	HOLE NO. ________

PROJECT: ________

CLIENT: ________

CONTRACTOR: ________

FILE NO. ________

SHEET NO. ________

LOCATION: ________

ELEVATION: ________

DATE START: ________

DATE FINISH: ________

DRILLER: ________

INSPECTOR: ________

GROUNDWATER		DEPTH TO:		
Date	Time	Water	Bottom of Casing	Bottom of Hole

	CASING	SAMPLER	CORE BARREL
Type:			
Size I.D.:			
Hammer Wt.:			
Hammer Fall:			

Scale in Feet	Strata Change	Casing Blows Per Foot	Sampler Blows Per 6 Inches	Sample Number	Sample Depth Range	FIELD CLASSIFICATION AND REMARKS

BLOWS/FT.	DENSITY	BLOWS/FT.	CONSISTENCY
0–4	Very Loose	0–2	Very Soft
4–10	Loose	2–4	Soft
10–30	Medium Compact	4–8	Medium Stiff
30–50	Compact	8–15	Stiff
50+	Very Compact	15–30	Very Stiff

SAMPLE IDENTIFICATION

S ____ Split Spoon

T ____ Thin Wall Tube

U ____ Undisturbed Piston

O ____ Open End Rod

W ____ Wash Sample

SUMMARY

Overburden: ________

Rock: ________

Samples: ________

HOLE NO. ________

H & A FORM 4 JAN 78

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

TEST BORING REPORT

HOLE NO.

PAGE OF

Scale in Feet	Strata Change	Casing Blows Per Foot	Sampler Blows Per 6 Inches	Sample Number	Sample Depth Range	FIELD CLASSIFICATION AND REMARKS

BLOWS/FT.	DENSITY	BLOWS/FT.	CONSISTENCY	SAMPLE IDENTIFICATION	SUMMARY
0—4	Very Loose	0—2	Very Soft	S ______ Split Spoon	Overburden: ______
4—10	Loose	2—4	Soft	T ______ Thin Wall Tube	Rock: ______
10—30	Medium Compact	4—8	Medium Stiff	U ______ Undisturbed Piston	Samples: ______
30—50	Compact	8—15	Stiff	O ______ Open End Rod	
50+	Very Compact	15—30	Very Stiff	W ______ Wash Sample	HOLE NO. ______

H&A FORM 4r
SEP. 78

HALEY & ALDRICH, INC. CAMBRIDGE, MASSACHUSETTS	TEST PIT REPORT	TEST PIT NO.

PROJECT: ________

CLIENT: ________

CONTRACTOR: ________

EQUIPMENT USED: ________

FILE NO. ________

LOCATION: ________

ELEVATION: ________

EXPLORATION DATE: ________

INSPECTOR: ________

Scale in Feet	Strata Change	Sample Number	Sample Depth Range	DESCRIPTION OF MATERIALS	REMARKS
2					
4					
6					
8					
10					
12					

GROUNDWATER		
DATE	TIME*	DEPTH/FT.
NOT ENCOUNTERED	* HRS. AFTER COMPL.	

______ x ______ x ______ = ______ Cu. Ft.
(L) (W) (D)

BOULDERS

8" to 18" DIAM: No. ______ = Vol. ______ Cu. Ft.

Over 18" DIAM: No. ______ = Vol. ______ Cu. Ft.

SUMMARY

DEPTH ______

JAR SAMPLES ______

BAGSAMPLES ______

GROUNDWATER ______

TEST PIT NO.

H & A FO: NOV. 78 24

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

GROUND WATER OBSERVATION WELL REPORT

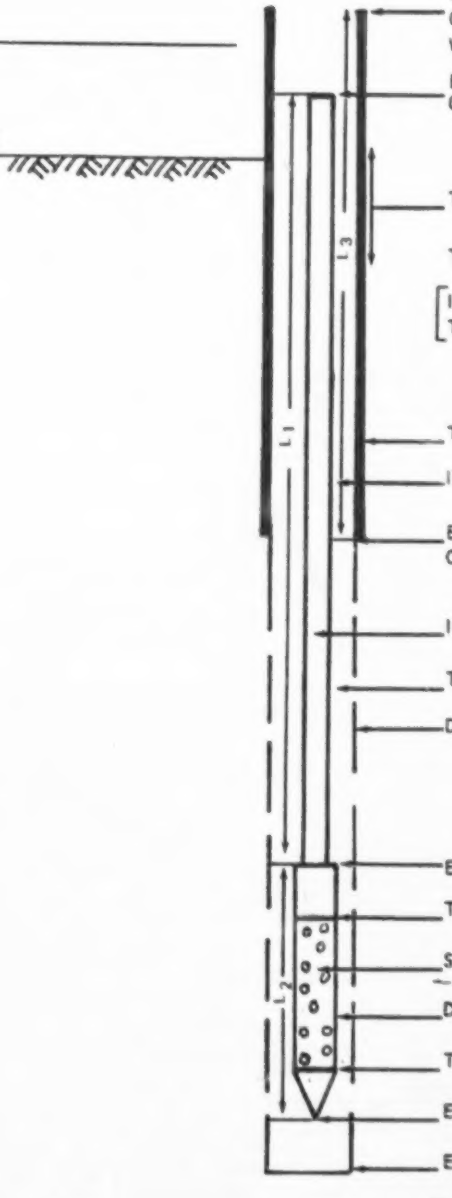
PROJECT: ______
LOCATION: ______
CLIENT: ______
CONTRACTOR: ______
DRILLER: ______ INSPECTOR: ______
INSTALLATION DATE ______

FILE NO. ______
WELL NO. ______
BORING NO. ______
LOCATION ______
______
SHEET ______ OF ______

SURVEY DATUM ______

GROUND ELEVATION

SUMMARIZE SOIL CONDITIONS (NOT TO SCALE)



ELEVATION OR STICKUP ABOVE/BELOW GROUND SURFACE OF CASING OR ROADWAY BOX ______
ELEVATION OR STICKUP ABOVE/BELOW GROUND SURFACE OF RISER PIPE. ______
THICKNESS OF SURFACE SEAL ______
TYPE OF SURFACE SEAL ______
[INDICATE ALL SEALS SHOWING DEPTH, THICKNESS AND TYPE]
TYPE OF CASING ______
INSIDE DIAMETER OF CASING ______
ELEVATION/DEPTH OF BOTTOM OF CASING ______
INSIDE DIAMETER OF RISER PIPE ______
TYPE OF BACKFILL AROUND RISER ______
DIAMETER OF BOREHOLE ______
______
ELEVATION/DEPTH OF BOTTOM OF RISER ______
TYPE OF POINT OR MANUFACTURER ______
SCREEN GAUGE OR SIZE OF OPENINGS ______
DIAMETER OF WELLPOINT ______
TYPE OF BACKFILL AROUND POINT ______
ELEVATION/DEPTH OF BOTTOM OF POINT ______
ELEVATION/DEPTH OF BOTTOM OF BOREHOLE ______

[FIGURES REFER TO: EL. ______ DEPTH ______]

[______ LENGTH OF CASING L_3] [______ LENGTH OF RISER PIPE (L_1) + ______ LENGTH OF POINT (L_2) = ______ PAY LENGTH]

H & A FORM 59 SEP. 72

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

GROUND WATER MONITORING REPORT

OW/PZ NUMBER: ____________

ELEVATION SUBTRAHEND ____________

FILE NO. ____________

PAGE NO. ____________

DATE	TIME	ELAPSED TIME	DEPTH OF WATER FROM ________	ELEVATION OF WATER	REMARKS	READ BY

H&A FORM JAN. 79 59A

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

PIEZOMETER INSTALLATION REPORT

PROJECT: ______

LOCATION: ______

CLIENT: ______

CONTRACTOR: ______

DRILLER: ______ INSPECTOR: ______

INSTALLATION DATE ______

FILE NO. ______

INSTRUMENT TYPE ______

INSTRUMENT NO. ______

LOCATION ______

SHEET ______ OF ______

DEPTH IN FEET	ELEV. IN FEET	INSTALLATION DIAGRAM	INSTALLATION COMMENTS

[LENGTH OF CASING] [LENGTH OF RISER PIPE] + [LENGTH OF POINT] = [PAY LENGTH]

H&A FORM 80
Aug. 76

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

BOREHOLE SEALING REPORT

HOLE NO.

PROJECT:
CLIENT:
CONTRACTOR:

FILE NO.
LOCATION:
ELEVATION:
DATE:
TIME START:
TIME FINISH:
DRILLER:
INSPECTOR:
GEOLOGIST:

	GROUT PLANT	GROUT PUMP	GROUT RODS
TYPE			
MANUFACTURER			
MODEL			

	CEMENT (LBS. - BAGS*)	ADDITIVE (LBS. - GALS.)	WATER (GALS)	FINAL QUANTITY CONSUMED (GALS)
TYPE				
MANUFACTURER				
QUANTITY				

* 1 BAG = 94 POUNDS

DEPTH TO: (FEET)
GROUNDWATER:
TOP OF ROCK:
BOTTOM OF HOLE:
(BEFORE GROUTING)
BOTTOM OF HOLE:
(AFTER GROUTING)

LENGTH TO GROUT:
LENGTH GROUTED:
DATE:

CEMENT SLURRY REQUIRED FOR 100 FT. HOLE

BOREHOLE DIMENSIONS		TOTAL VOLUME IN 100 FOOT HOLE		WATER PER SACK OF CEMENT (GAL.)	VOLUME OF SLURRY PER SACK OF CEMENT (CU. FT.)	NO. OF BAGS OF CEMENT FOR 100 FT. HOLE	WATER REQUIRED PER 100 FT. HOLE (GAL.)
DRILL HOLE SIZE	HOLE DIA. (IN.)	CUBIC FEET	GALLONS				
BX	2-3/8	3.07	22.9	5	1.15	2-3/4	13-1/2
				10	1.82	1-3/4	17
				15	2.48	1-1/4	18-1/2
NX	3	4.90	36.7	5	1.15	4-1/4	21
				10	1.82	2-3/4	27
				15	2.48	2	29-1/2

CALCULATIONS

PROCEDURE UTILIZED:

CONCLUSIONS AND ENGINEERING SIGNIFICANCE:
(Based on Final Quantity Consumed)

H&A Fo Jun. 73

HALEY & ALDRICH, INC.
CONSULTING SOIL ENGINEERS

VANE SHEAR REPORT

HOLE NO. **TEST NO.**

FILE NO: ____________
DATE: ____________
GROUND EL: ____________
LOCATION: ____________
TEST EL: ____________
WATER EL: ____________
DRILLER: ____________
INSPECTOR: ____________

PROJECT: ____________
CLIENT: ____________
CONTRACTOR: ____________

CASING SIZE	DEPTH TO BOTTOM OF:	METHOD USED TO ADVANCE VANE	TORQUE ARM LENGTH (IN.)
____________	CASING ____________ ft. VANE ____________ ft.	____________	____________

SOIL DESCRIPTION: ____________
VANE DIMENSIONS AND REMARKS: (SEE REVERSE SIDE)

UNDISTURBED CONDITION				REMOLDED CONDITION				FRICTION ON VANE SHAFT			
TIME	ANGULAR ROTATION	FORCE GAUGE READINGS		TIME	ANGULAR ROTATION	FORCE GAUGE READINGS		TIME	ANGULAR ROTATION	FORCE GAUGE READINGS	
MIN-SECS	DEGS.	DIV.	LBS.	MIN-SECS	DEGS.	DIV.	LBS.	MIN-SECS	DEGS.	DIV.	LBS.

SHEAR STRENGTH DETERMINATION	UNDISTURBED	REMOLDED
MAXIMUM FORCE GAUGE READING FOR VANE, V (lb.)		
MAXIMUM FORCE GAUGE READING FOR SHAFT, H (lb.)		
NET FORCE, F (lb.) = V−H		
APPLIED TORQUE, T (in.-lb.) = F x TORQUE ARM (in.)		
SHEAR STRENGTH, S(psf) = VANE CONSTANT, K x T = ________ x T		

$$\text{SENSITIVITY} = \frac{S\ (\text{undisturbed})}{S\ (\text{remolded})} = \_\_\_\_\_\_\_\_\_\_\_\_$$

H&A FORM MAY 72

FIELD VANE DESCRIPTION

MANUFACTURER: ____________________

DIMENSIONS: H = ____________ in.

$h_t{}^*$ = ____________ in.

$h_b{}^*$ = ____________ in.

D = ____________ in.

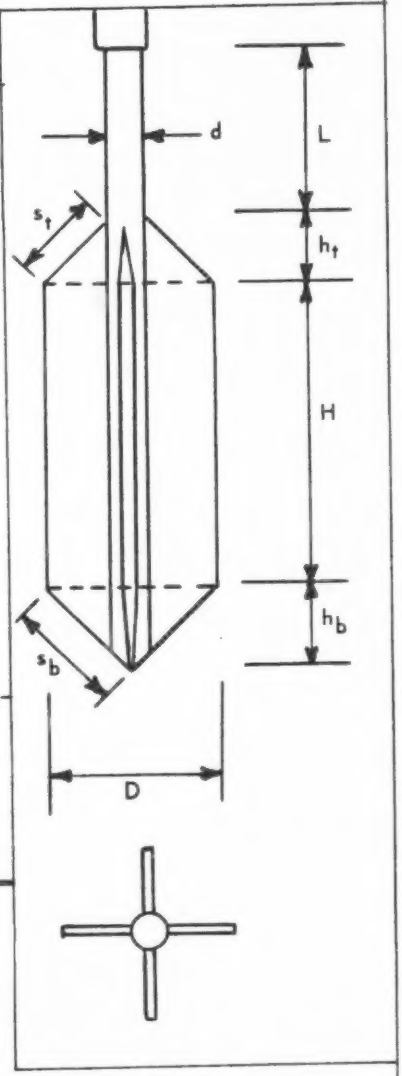
d = ____________ in.

$s_t{}^*$ = ____________ in.

$s_b{}^*$ = ____________ in.

L = ____________ in.

VANE CONSTANT, K = ____________ psf/in.-lb.



*FOR RECTANGULAR VANE:

$h_t = h_b = 0$ and

$s_t = s_b = D/2$

TORQUE HEAD ASSEMBLY

MANUFACTURER: ____________________

FORCE GAUGE: TYPE ____________ NO. ____________

Calibration: 1 Division = ________ lb.

REMARKS: ____________________

HALEY & ALDRICH, INC.
CAMBRIDGE, MASSACHUSETTS

FIELD PERMEABILITY TEST REPORT

PROJECT: ____

LOCATION: ____

CLIENT: ____

CONTRACTOR: ____

DRILLER: ____ INSPECTOR: ____

INSTALLATION DATE ____ TEST DATE ____

FILE NO. ____

WELL NO. ____

BORING NO. ____

LOCATION ____

SHEET ____ OF ____

TYPE INSTALLATION ____

TYPE TEST ____

TYPE CASING ____ LENGTH ____ I.D. ____

TEST SECTION LENGTH ____ I.D. ____

SOIL DESCRIPTION ____ H_2O TEMP. ____

ELEVATIONS – SURVEY DATUM ____

GROUND SURFACE ____ STATIC WATER ____

TOP OF CASING ____ BOTT. OF CASING ____

TOP OF TEST ____ BOTT. OF TEST ____

REMARKS/SKETCH

PERMEABILITY TEST DATA

TIME (MINS-SECS)	ELAPSED TIME	METER READING	WATER QUANTITY	DEPTH TO WATER FROM ____	ELEVATION OF WATER

H&A FORM 69
MAR 76

SUBSURFACE EXPLORATION SUMMARY
TEST BORING NO. ____________

PROJECT TITLE ______________________ GROUND ELEVATION (M/FT) ____________
PROJECT LOCATION ______________________ WATER ELEVATION (M/FT) ____________
UTILITY COMPANY ______________________ DATE COMPLETED ____________

ELEV METERS/FEET	DEPTH (FEET)	SAMPLE TYPE + NUMBER	SYMBOL	USCS	TEST TYPE+NO	DESCRIPTION	WELL/PIEZ INSTALLATION SKETCH	STANDARD PENETRATION TEST (SPT) [BLOWS/FT (N)] 20 40 60 80
	2							
	4							
	6							
	8							
	10							
	12							
	14							
	16							
	18							
	20							
	22							
	24							
	26							
	28							
	30							
	32							
	34							
	36							
	38							
	40							
	42							
	44							
	46							
	48							
	50							
	52							
	54							
	56							
	58							
	60							
	62							
	64							
	66							
	68							
	70							